COMBUSTION

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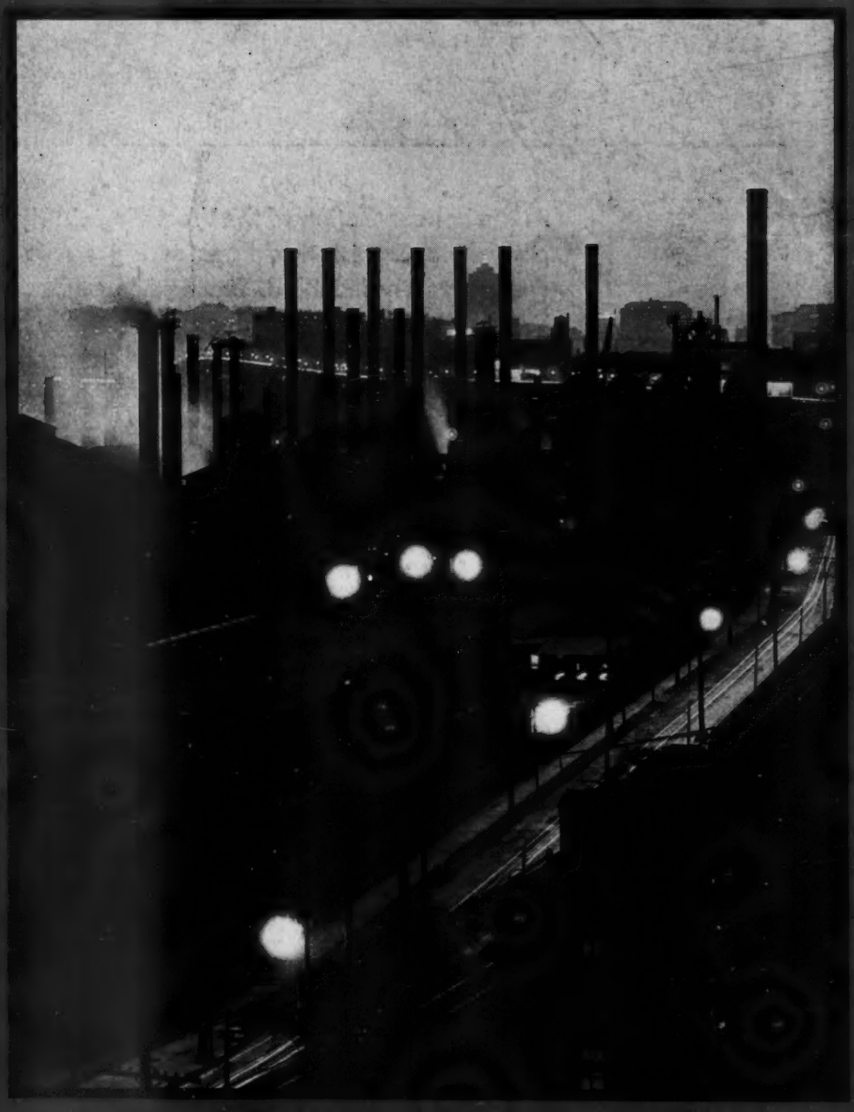

Natural Gas as Fuel for Power Plants
By E. A. BENDING

Dual Purpose Power Plants
for Commercial Distribution of High Pressure Steam
By JOHN M. DRABELLE

OTHER ARTICLES IN THIS ISSUE BY
O. G. ZAPPE • JULIUS KLEIN • C. H. S. TUPHOLME • B. J. CROSS • EUGENE HAHN • DAVID BROWNLIE

WALSH-WEIDNER BOILERS SERVE NEW STEAM PLANT OF WEST VIRGINIA HYDRO-ELECTRIC

West Virginia Hydro-Electric Plant, Boncar, W. Va.

At the Boncar Station of the West Virginia Hydro-Electric Company, two Combustion Engineering steam generating units were recently installed. These units each comprise a Walsh-Weidner Sectional-Header Boiler of the single-pass type, Lopulco Direct-Fired Pulverized-Fuel System, and C-E Water-Cooled Furnace.

Each boiler is 30 sections wide, 42 tubes high, and contains 31,825 sq. ft. of heating surface; working pressure, 488 lb. per sq. in.; total steam temperature, 760 deg. fahr. The maximum capacity of each unit is 325,000 lb. of steam per hour.

The fact that each of these units is to supply steam for a 30,000 kw. generator is an indication of the absolute confidence placed in the reliability of C-E steam generating units.

• • •

A Condensed Catalogue, which briefly describes the Walsh-Weidner boiler and all other Combustion Engineering products, will be sent to you upon request.

COMBUSTION ENGINEERING CORPORATION

200 MADISON AVENUE • NEW YORK

Looking up into the Walsh-Weidner Boiler from the bottom of the furnace.

COMBUSTION

VOLUME THREE • NUMBER ONE

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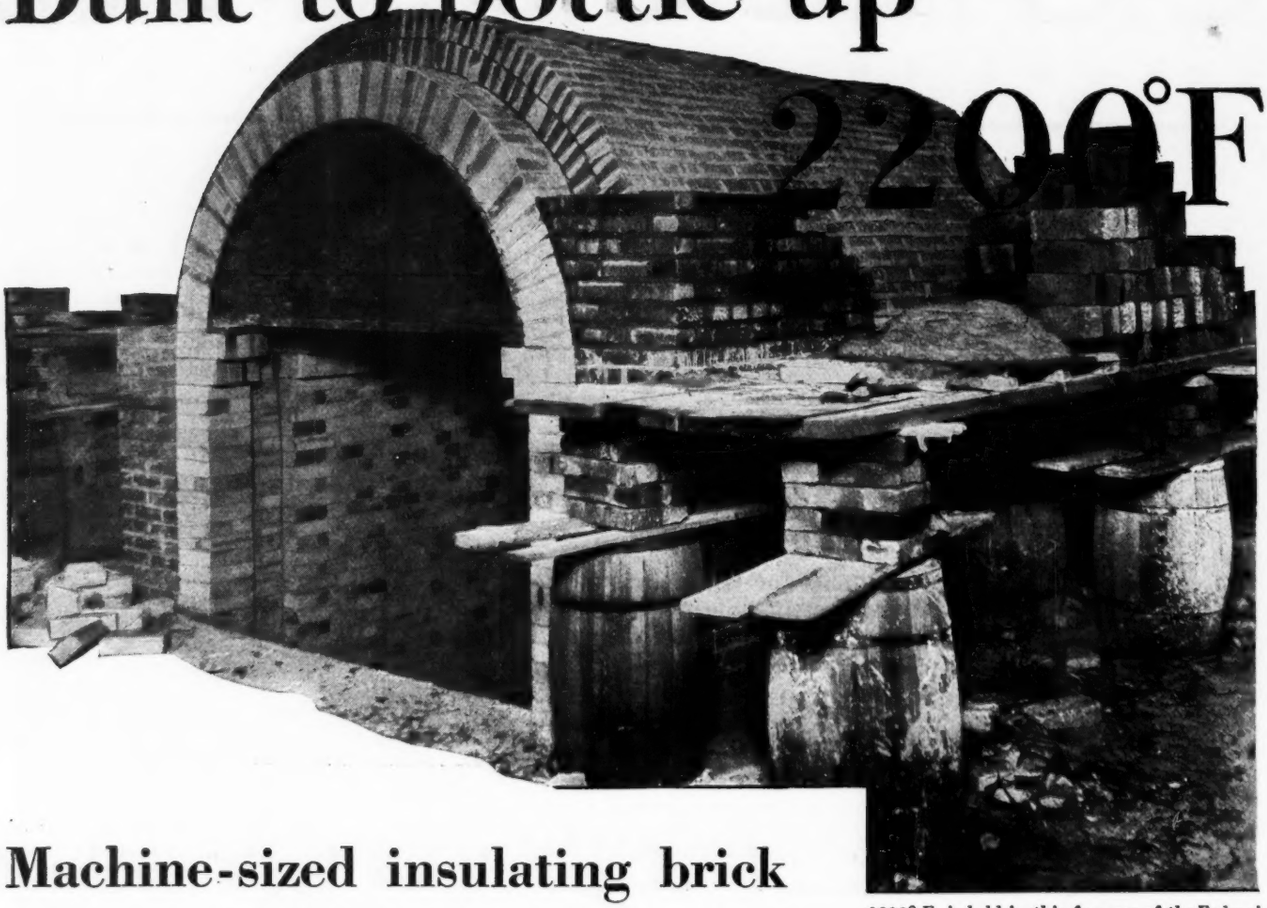
Built to bottle up 2200°F



Machine-sized insulating brick prevent costly heat waste . . . . .

2200° F. is held in this furnace of the Federal Enamel & Stamping Company, at McKees Rocks, Pa., by means of a 9" layer of Nonpareil Insulating Brick.

FURNACES are made to generate high temperatures and *keep them*. Heat dissipated through walls and doors represents pure waste of fuel. That's why high temperature furnaces—such as the furnace of the Federal Enamel & Stamping Company—call on insulating brick to bottle up heat.

Nonpareil and Armstrong's Insulating Brick furnish double insurance against wasted heat. Because of their low coefficient of thermal conductivity, they permit a minimum of B. t. u.'s to escape. And because they are machine-sized on all flat surfaces, they lay up tighter and supply more uniform resistance to heat.

Armstrong's Insulating Brick are burned at kiln temperatures of more than 2500° F., which guarantees that they will resist equally high temperatures without warping, fusing, or spalling. Nonpareil are burned at 1600° F., and will withstand temperatures up to this point. Temperatures referred to are behind the refractory, at the face of the insulating brick. In the furnace shown above, a 9 inch layer of Nonpareil Brick was used. Temperature behind the refractory was low enough to permit Nonpareil Brick to be used safely, although the heat inside the furnace was as high as 2200° F.

Armstrong engineers are at your service for consultation on any high temperature insulating work. Their years of experience in this field may suggest ways of saving you money on installations. You will want to ask them, too, about the technical phases of these brick—their weight, crushing strength, workability, and construction. If you prefer, we will gladly send you samples of each for your own tests. Address Armstrong Cork & Insulation Company, 934 Concord St., Lancaster, Pennsylvania.

Armstrong's (A) Product

Armstrong's and Nonpareil Insulating Brick

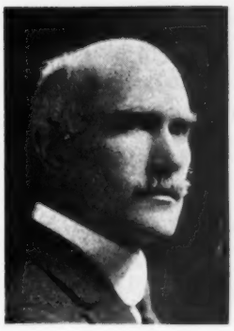
for FURNACES, OVENS, KILNS, and LEHRS

Engrg.

COMBUSTION

VOLUME 3 JULY 1931 NUMBER 1

Boiler Feed Water Conditioning



E. R. FISH

EVER since steam has been produced in quantities for industrial purposes, boiler operators have been perplexed, hampered and annoyed by the formation of scale on the interior surfaces. The development of chemistry gradually suggested means for entirely or partially preventing these depositions and also gave rise to a great variety of "quack cure-alls" which were used all too widely because of the general ignorance of chemical principles on the part of users.

Due to the low rates of evaporation and low furnace temperatures prevalent until comparatively recently, accumulations did not cause any great concern. If feed water treatment were not used or were not entirely effective the accumulations were more or less frequently removed as well as possible by mechanical means.

Recent developments in prime movers, notably the steam turbine, resulted in a revolution in boiler practice. Not only have rates of evaporation been increased several times, but steam pressures have mounted rapidly. While under the older order, overheating of boiler parts, decreased efficiencies and steam pipe line and engine troubles, easily traced to scale and inadequate feed water treatment, were not usually very serious, under the newer order the presence of any foreign substances on the heating surfaces of a boiler is a serious menace. The least interference with the rapid absorption of heat is instantly reflected by a failure of some sort. High pressures add greatly to the dangers. Any concentration of foreign solubles in the boiler water almost inevitably becomes manifest in foaming or priming, and the tremendously increased ratings now customary aggravate the difficulty. Wet steam or slugs of water create havoc with pipe lines and prime movers. The superheater suffers in efficiency through having to evaporate moisture, thereby accumulating solids on surfaces from which heat is at best not rapidly absorbed. Dust is also formed and carried to the prime mover to cause excessive erosion of turbine blades or cylinder walls.

All of these objectionable phenomena stimulated laborious research by a large number of competent engineers and chemists who have evolved various methods of treatment of raw feed water. It is now possible to so change the characteristics of feed as to prevent scale altogether and to reduce concentration to unobjectionable limits. To operate a boiler in such a way as to produce dangerous conditions, due to the character of the water, is exceedingly reprehensible and absolutely unnecessary.

What the monetary losses have been, due to deterioration of boilers and other apparatus, as well as to actual failures and consequent outages that have occurred because of improper handling of the feed, can never be known but there are many operators whose personal experiences would justify a large estimate.

There are now available to those who have to use all or a large proportion of make-up, the services of many men and companies who are competent to advise intelligently. Since the nature of the water usually varies, not only from season to season, but from day to day, constant attention is necessary.

Therefore, it cannot be too strongly emphasized that any plant operating under modern conditions cannot afford to minimize the importance of this question nor to neglect its proper attention.

E R Fish

Chief Engineer, Boiler Division,
The Hartford Steam Boiler, Inspection & Insurance Co.

EDITORIAL

Welded Pressure Vessels

FUSION welding, a new method of boiler drum fabrication, is rapidly gaining recognition. This process holds promise of becoming the most important advancement in boiler manufacture since the introduction of the seamless forged header.

Progress is inevitable—it cannot be denied, but too often its path is strewn with the costly and needless failures of incapable and over-ambitious organizations who blunder along in the wake of the pioneers, seeking to reap an undeserved share of the rewards of costly and laborious development to which they have contributed nothing.

Imitation is said to represent flattery in its highest degree.

That it may not also prove a severe handicap to the advancement and wide adoption of fusion welded pressure vessels, codes, regulations—legislation if need be—should provide for limiting the use of this newly developed process in boiler drum fabrication, to those organizations which can qualify as to the correctness of their methods, the adequacy of their equipment, the competency of their workmen, and the reliability of their methods of testing and inspection.

With the trend toward higher pressures, higher temperatures, larger units and increased ratings, there is every incentive for both buyer and seller to guard against faulty methods and workmanship in every type of boiler construction.

Collateral Developments Influence Steam Practice.

Whenever it appears that progress in any particular field has reached a state which permits of little further improvement, those who are prone to accept the "status quo" of things are apt to find themselves suddenly confronted by new and highly significant possibilities.

This thought is well exemplified in the field of steam and power generation at the present time. In modern steam power plants, the thermal efficiencies secured are admittedly high and there is apparently little room for improvement. Nevertheless collateral developments are under way which, in their eventual form, will greatly improve the overall economy of both central stations and the larger industrial plants.

Some of these developments are discussed in this issue of COMBUSTION in the articles by John Drabelle and David Brownlie.

Mr. Drabelle describes several dual-service power stations, supplying both power and steam for heating and process purposes to surrounding manufacturing establishments; also plants operated on a cooperative basis by utilities and industrials with a nearly ideal balance of steam and electric load.

Mr. Brownlie discusses similar trends as exemplified by the Landerbrugge station in Belgium and the new Ford plant near London.

The engineer of today who aspires to a large measure of success must not only be capable of contributing to improved practice in his chosen field but must be intelligently cognizant of collateral developments, which may not only affect but may largely shape that practice.

A Rift in the Clouds

DURING the past several weeks certain equipment manufacturers have noticed a definite increase in the number of small and medium size contracts for mechanical equipment.

Still more encouraging is the fact that this new business is coming from practically every section of the country—north, south, east and west—and from widely diversified industries.

Thus a general industrial improvement is indicated in contrast with the spotty and isolated buying which has marked the past year.

The present increase in the number of small contracts reflects the growing recognition on the part of industry that equipment prices are at bedrock. Shrewd purchasers realize that present day prices can go no lower as, in most instances, they are but little above actual manufacturing costs. Industry will not—cannot—operate for long without reasonable profit. Furthermore, with the inevitable upturn of business, these prices are certain to increase and deliveries will lengthen in proportion to the volume of new business.

Today steam plant equipment is being quoted at prices which would have been attractive even before the war and never before has this class of apparatus offered the refinements of design, reliability of performance and efficiency of operation which characterize modern power equipment.

The economic situation today makes it imperative that steam costs be at a minimum in all plants from the smallest industrials to the largest public utilities. This is axiomatic. The replacement of antiquated and inefficient apparatus is the most direct route to this result. The cost of replacement is ofttimes referred to as the cost of obsolescence. Julius Klein prefers to call it "the price of progress." His interpretation is unquestionably the more constructive.

The present definite increase in equipment purchases reflects the judgment and acumen of industrial executives who are now purchasing quality apparatus at bargain prices.

Natural Gas as Fuel in Power Plants

By
E. A. BENDING
Combustion Engineer
Middle West Utilities Co.

With the extension of natural gas pipe lines to many parts of the country and the plans that are under way for the still further distribution of this fuel, its use both in central power stations and industrial plants has become a matter of immediate interest. Mr. Bending has contributed a very able and comprehensive article on this subject. The data and information he presents should be of practical value to many plant operators who are, or shortly may be, in a position to make use of this highly economical and desirable fuel.

NATURAL gas might be termed as the ideal, the perfect fuel. It is delivered at its required destination mostly under its own pressure, distributes easily, is easily controlled, ignites immediately, burns readily. There is no smoke, no clinkers or cinders, no ash. It is adaptable to a laboratory burner, a small hot plate in a breakfast nook, or under a mighty steam generator, as well as for all industrial uses. And, where available, it is usually cheaper than any other fuel.

The first commandment in burning natural gas is, as with any fuel, "know thy fuel."

Table 1 gives analyses and B.t.u. of gases from various sections, and most of the pipe lines extensions to various parts of the United States are from some of these localities.

It will be noted that there is considerable variation in the percentages of the constituents and B.t.u. The principal constituents are Methane (CH_4) and Ethane (C_2H_6) and, the higher the percentage of Ethane, the higher the B.t.u. which, in this list, varies from 950 to 1500 B.t.u. per cu. ft. (See Table 3 "Heat of Combustion").

Table 2 gives the different constituents of natural gas, the proportions in relation to one another, as well as the oxygen and air required for theoretically perfect combustion, and the products of combustion. From the proportions, the amount of carbon, hydrogen and sulphur may be computed in weight, and from the requirements and products may be computed the results for any given gas analysis. Table 3 gives the theoretical heating value of the various constituents as well as ignition temperatures.

There are two heating values given. The lower

TABLE 1—TYPICAL ANALYSES AND B. T. U. OF NATURAL GAS
Different Localities

	CO_2	O_2	N_2	CH_4	C_2H_6	B.t.u.	Sp. G.
Osage County, Okla.	1.10	0.0	4.6	94.3	0.0	1004	.058
Kiefer, Okla.	2.40	0.0	1.8	64.1	31.7	1272	.074
Marshall, Texas	.22	.8	6.6	86.70	3.38	998	.048
Cisco, Texas	0.00	1.0	12.0	66.00	21.00	1043	.057
Schulto Field, Okla.	.50	0.0	1.5	76.4	21.6	1215	.072
Park County, Okla..	0.00	0.0	1.8	94.4	3.8	1076	.056
Caddo Parish, La....	.90	0.0	1.5	97.6	0.0	1039	.057
Barron County, Ky..	2.50	0.0	1.3	23.6	69.7	1548	.092
Moab, Utah	3.60	0.0	5.6	90.8	0.0	967	.046
Abilene, Texas	0.00	0.3	4.60	74.0	20.60	1129	.055
Leavenworth, Kansas	0.80	0.6	6.30	88.9	3.40	964	.047
Lawton, Okla.	0.02	0.06	.06	86.7	.04	960	.047
Quanah, Texas	0.2	0.4	5.8	85.5	9.1	1011	.056

TABLE 2—DATA OF CONSTITUENTS OF NATURAL GAS
(The values given are in pounds per pound of combustible)

Constituents found in Natural Gas	Symbol	Rel. Den.	Relative Proportions	B.t.u. Gross	Req'd for Combustion: O_2	Req'd for Combustion: Air	Flue Products: CO_2	Flue Products: H_2O	Flue Products: N_2	Wts. per cu. ft.
Carbon Monoxide	CO	14	3/7 — 4/7	4362	0.571	2.471	1.571	....	1.900	.07405
Hydrogen	H_2	1	.....	61397	7.940	34.357	....	8.939	26.417	.00532
Methane	CH_4	8	3/4 — 1/4	24102	3.992	17.274	2.745	2.248	13.282	.04244
Ethane	C_2H_6	15	4/5 — 1/5	22333	3.728	16.131	2.929	1.799	12.403	.08033
Ethylene	C_2H_4	14	6/7 — 1/7	21969	3.425	14.820	3.139	1.285	11.395	.07464
Hydrogen Sulphide.....	H_2S	17	1/16—15/16	.....	1.408	6.093	(SO_2) 1.880	.529	4.685	.09113
Oxygen	O_2	16	.....	.....	....	.....	....	....	.....	.08462
Carbon Dioxide	CO_2	22	3/11— 8/11	.....	....	.....	....	....	.....	.11707
Nitrogen N_2	N_2	14	.....	.....	....	.....	....	....	.....	.07443
Carbon C	C (Gas)	.82	.....	14540	2.666	11.536	3.667	....	8.87	.0668
Sulphur	S_2	16	.....	4050	1.000	4.32	(SO_2) 2.00	....	3.32	.....

or net is used in Great Britain and other countries, but the higher value is recommended by the American Association of Mechanical Engineers, and is accepted as the standard in this country.

TABLE 3—HEAT OF COMBUSTION

Combustible	Symbol	Heating Value B.t.u. per Lb. Higher	Heating Value B.t.u. per Lb. Low or Net	B.t.u. Cu. Ft. Higher	Ignition Temperatures Deg. Fahr.
Hydrogen	H_2	62000	52920	348	1130
Methane	CH_4	23850	21670	1073	1202
Ethylene	C_2H_4	21450	20420	1675	1022
Ethane	C_2H_6	22230	20500	1883	1000
Acetylene	C_2H_2	21460	21020	1590	900
Carbon (to CO)	C	4380	.....	....	....
Carbon (to CO_2)	C	14540	.....	....	....
Carbon Monoxide	CO	4380	.....	....	1210
Sulphur (to SO_2)	S_2	4050	.....	....	470
Sulphur (to SO_3)	S_2	5940	.....	....	....

This difference in value, as represented by the lower heating value, attempts to take into consideration the losses due to moisture formed in burning hydrogen, but inasmuch as the total or higher value is included in the constituents and a "heat balance," without which no test is complete, indicates this loss, there is no reason for not using the higher value in computing efficiencies.

Table 3 gives the heat of combustion of various elements or combinations usually found in natural gas and also ignition temperatures.

With the foregoing data at hand, we may now consider a typical gas analysis (Table 4). This particular gas comes from Texas' Amarillo field and is delivered at Leavenworth, Kansas.

TABLE 4—FUEL ANALYSIS & COMBUSTION DATA
NATURAL GAS—LEAVENWORTH STATION

Calculated B.t.u. per cu. ft. at 30 in. & 60 deg. fahr. 264

Methane	CH_4	Per Cent	88.9
Ethane	C_2H_6	Per Cent	3.4
Carbon Dioxide	CO_2	Per Cent	0.8
Oxygen	O_2	Per Cent	.6
Nitrogen	N_2	Per Cent	6.3
			100.00

Converting analysis by volume to one by weight at 60 deg. fahr.

	V. per Cu. Ft.		Wt. per Cu. Ft.		Wt. Lb.			Per Cent by Wt.
CH_4	.8890	×	.04258	=	.037854	÷ .046673	=	81.11
C_2H_6	.0340	×	.08014	=	.002725	÷ .046673	=	5.84
CO_2	.0080	×	.11676	=	.000934	÷ .046673	=	2.00
O_2	.0060	×	.08441	=	.000506	÷ .046673	=	1.08
N_2	.0630	×	.07387	=	.004654	÷ .046673	=	9.97
	1.0000				.046673 lb. per cu. ft.			100.00

Wt. per cu. ft. at 60 deg. fahr. and 30 in. Hg.—.046673 lb.
Cu. Ft. per lb.—21.425 Cu. Ft.

WEIGHTS OF OXYGEN & AIR FOR PERFECT COMBUSTION AND WEIGHTS OF PRODUCTS

Constituents	Wt. per Lb. Gas Lb.	Required Lb. O_2	Required Lb. Air	Products of Combustion—Lb. per Lb. Gas CO_2	O_2	N_2	H_2O	SO_2
CH_4	.8111	3.244	14.016	2.230	...	10.771	1.825	....
C_2H_6	.0584	.218	.942	.171	...	.724	.105	....
CO_2	.0200	....	.....	.020	...	.....	....	....
O_2	.0108	....	.....	....	.011	.....	....	....
N_2	.0997	....	.....	....	...	.100	....	....
Total	1.0000	3.462	14.958	2.421	0.11	11.595	1.930	....
Less O_2 in Gas	.011	.047	....	—.011	—.036	....	....	
Totals		3.451	14.911	2.421	...	11.559	1.930	....

Weight of air theoretically required *per lb.* of gas at 60 deg. fahr. and 30 in. Hg. ..... 14.911 lb.
Weight of air theoretically required *per cu. ft.* of gas at 60 deg. fahr. and 30 in. Hg. ..... .696 lb.
Weight of products of perfect combustion, lb. per lb gas ..... 15.910 lb.
Weight of dry products of perfect combustion, lb. per lb. gas ... 13.980 lb.

For each 10 per cent excess air supplied over and above 14.911 lb. there will appear in the products of combustion

1.4911 × .2315 equals .345 lb. of O_2
1.4911 × .7685 equals 1.146 lb. of N_2

A

	Weight Products Perfect Combustion	Weight of Products—Varying Amounts of Excess Air—Lb. 10%	15%	20%	30%	40%	50%
CO_2	2.421	2.421	2.421	2.421	2.421	2.421	2.421
O_2	.000	.345	.517	.690	1.035	1.380	1.725
N_2	11.559	12.705	13.278	13.851	14.997	16.143	17.289
H_2O	1.930	1.930	1.930	1.930	1.930	1.930	1.930
	15.910	17.401	18.146	18.892	20.383	21.874	23.365

B

	Per Cent Weight Products Perfect Combustion	Per Cent Weight Products—Varying Amounts Excess Air 10%	15%	20%	30%	40%	50%
CO_2	15.22	13.91	13.34	12.81	11.88	11.07	10.36
O_2	0.00	1.98	2.85	3.65	5.08	6.31	7.38
N_2	72.65	73.02	73.17	73.32	73.57	73.80	74.00
H_2O	12.13	11.09	10.64	10.22	9.47	8.82	8.26
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

C

	Per Cent Weight Dry Products Perfect Combustion	Per Cent Weight Dry Products—Varying Amounts Excess Air 10%	15%	20%	30%	40%	50%
CO_2	17.32	15.65	14.93	14.27	13.12	12.14	11.29
O_2	0.00	2.23	3.19	4.07	5.61	6.92	8.05
N_2	82.68	82.12	81.88	81.66	81.27	80.94	80.66
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

D

	Per Cent Volume Dry Products Perfect Combustion	Per Cent Volume Dry Products—Varying Amounts Excess Air 10%	15%	20%	30%	40%	50%
CO_2	11.70	10.53	10.03	9.58	8.78	8.11	7.53
O_2	0.00	2.08	2.97	3.78	5.20	6.40	7.43
N_2	88.30	87.39	87.00	86.64	86.02	85.49	85.04
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table D gives the per cents of CO_2, O_2 and N_2 obtainable with the various per cents of excess air, all in terms of per cent by volume, as it is by volume that Orsat readings are indicated.

With this gas, probably 10.53 per cent of CO_2 would carry some monoxide as 10 per cent excess air is getting very close to the critical point. Between 10 and 15 per cent of excess air represents excellent practice.

The per cents of carbon, hydrogen, oxygen and nitrogen may be calculated from the natural gas analysis. Methane is 3/4 carbon and 1/4 hydrogen by weight. Ethane is 4/5 carbon and 1/5 hydrogen by weight. Carbon dioxide is 3/11 carbon and 8/11 oxygen by weight. Therefore:

	% by Wt.	% C	% H_2	% O_2	% N_2
CH_4	81.11	60.83	20.28	....	....
C_2H_6	5.84	4.67	1.17	....	....
CO_2	2.00	.55	....	1.45	....
O_2	1.08	....	....	1.08	....
N_2	9.97	....	....	....	9.97
	100.00	66.05	21.45	2.53	9.97

The heating value of the gas may be determined also from the gas analysis:

	% by Wt.		Heating Value B.t.u. per Lb.		Heating Value of Gas per Lb.
CH_4	81.11	×	23,850	=	19,345
C_2H_6	5.84	×	22,230	=	1,298
CO_2	2.00		.....		.....
O_2	1.08		.....		.....
N_2	9.97		.....		.....
	100.00		.....		20,643 B.t.u.

Dividing 20,643 (B.t.u. per lb.) by 21.245 (cu. ft. per lb.), heating value per cubic foot of gas = 964 Bt.u.

HYPOTHETICAL HEAT BALANCE

Allowing 15% Excess Air		Ultimate Analysis	
CO_2	10.00	C	66.05%
O_2	2.97	H_2	21.45
CO	.03*	O_2	2.53
N_2	87.00	N_2	9.97
	100.00		100.00

* Assumed trace.

Escaping Flue Gases... 480° F.
Room Temperature.... 75° F.
B.t.u. per cu. ft. at 60° F. and 30 in. Hg.....964

Losses	B.t.u.	Per Cent
Loss due to burning of hydrogen	111.32	11.55
Loss due to heat in dry chimney gases	73.57	7.63
Loss due to incomplete combustion	.94	.10
Loss due to moisture in air radiation, etc.	11.76	1.22
Balance for Steam	766.41	79.50
	964.00	100.00

(Continued on page 24)

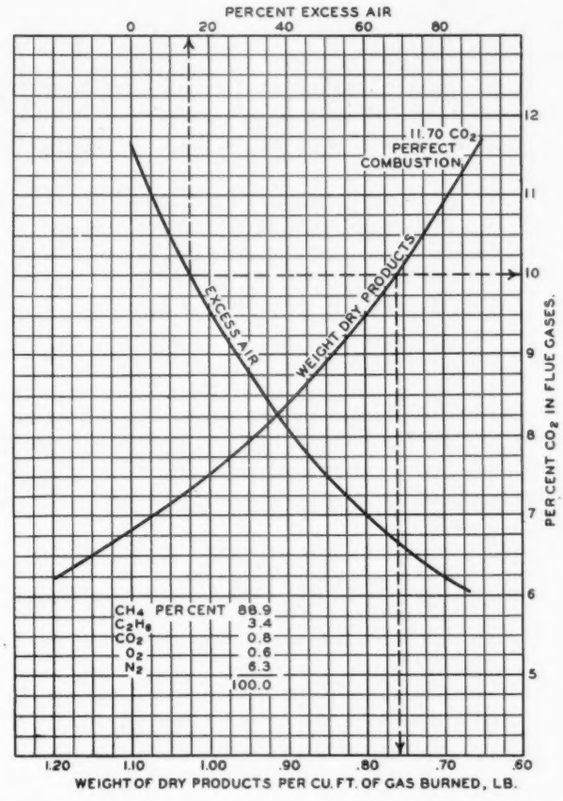


Fig. 1—Weight of dry stack gases for various amounts of excess air.

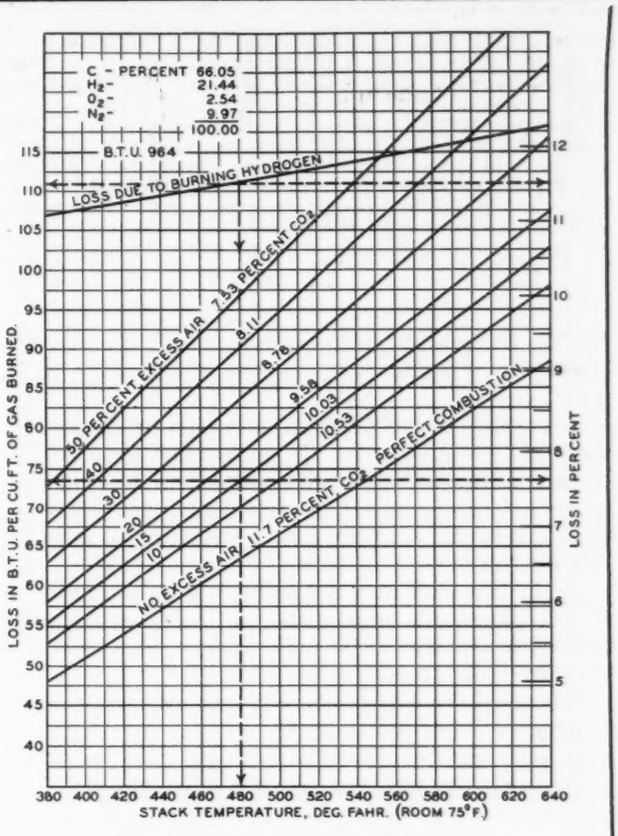


Fig. 2—Heat loss in dry stack gases.

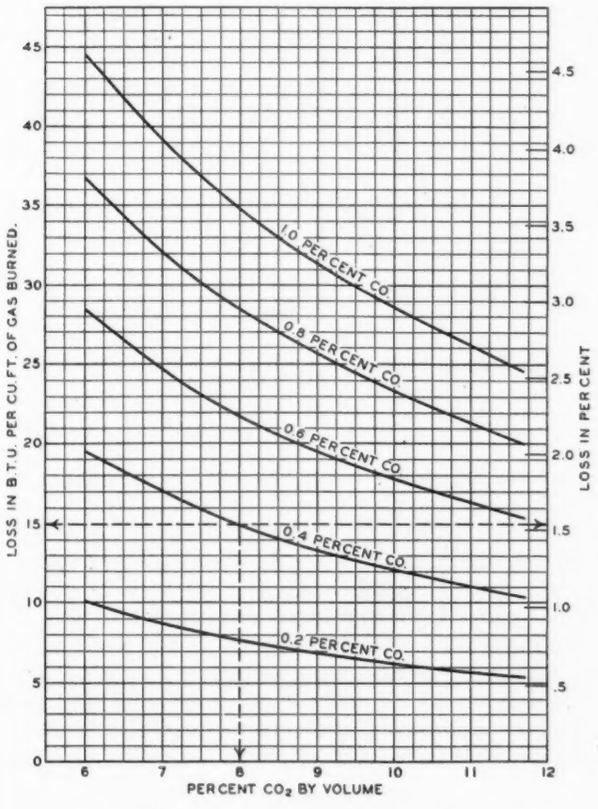

1.0 PERCENT CO.
0.8 PERCENT CO.
0.6 PERCENT CO.
0.4 PERCENT CO.
0.2 PERCENT CO.
LOSS IN B.T.U. PER CU. FT. OF GAS BURNED.
LOSS IN PERCENT
6 7 8 9 10 11 12
PERCENT CO_2 BY VOLUME

Fig. 3—Loss due to incomplete combustion.

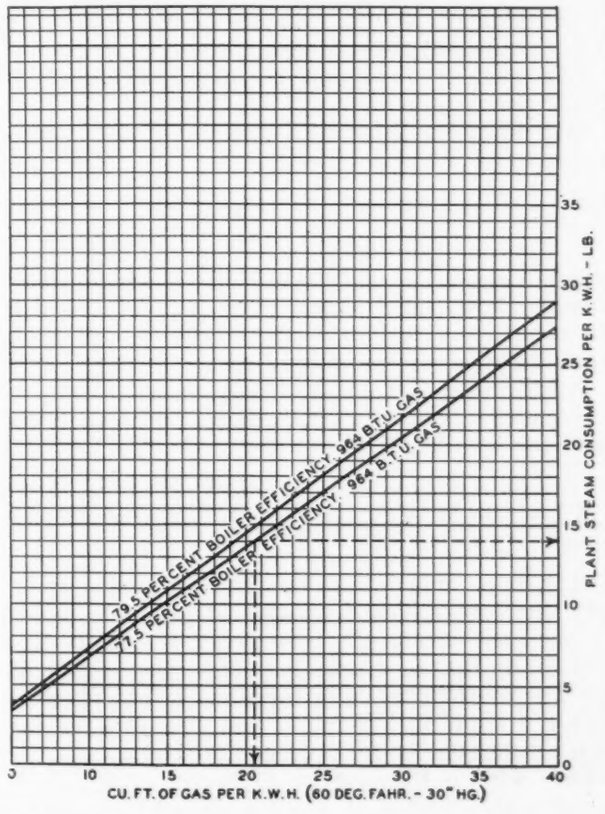

79.5 PERCENT BOILER EFFICIENCY, 964 B.T.U. GAS
77.5 PERCENT BOILER EFFICIENCY, 964 B.T.U. GAS
PLANT STEAM CONSUMPTION PER K.W.H. - LB.
0 10 15 20 25 30 35 40
CU. FT. OF GAS PER K.W.H. (60 DEG. FAHR. - 30" HG.)

Fig. 4—Cubic feet of gas per kw-hr. at various water rates. (1 lb. of gas equals 21.425 cu. ft. at 60 deg.—30 in.)

Operating boilers at 79.5 per cent efficiency, the evaporation from and at 212 deg. fahr. per cu. ft. of gas would be .790 lb. With a 1.133 factor of evaporation, the actual evaporation would be .697 lb. per cu. ft. of gas burned. The gas per boiler hp. would be 43.67 cu. ft. at 60 deg. fahr. and 30 in. Hg.

Gas per kw-hr. at 14 lb. station water rate—20.08 cu. ft.

Operating boilers at 77.5 per cent efficiency which allows 2 per cent for banks, starting fires, etc., and with 964 B.t.u. per cu. ft. of gas as fired, the equivalent evaporation would be .770 lb. With a 1.133 factor of evaporation, the actual evaporation would be .680 lb. per cu. ft. of gas burned. The gas per boiler hp. would be 44.81 cu. ft. at 60 deg. fahr.

Gas per kw-hr. at 14 lb. station water rate—20.59 cu. ft.

The foregoing computations and results are shown in graphic form on the charts Figs. 1, 2, 3 and 4.

This setup of combustion data tells us the proper amounts of oxygen or air, and what may be expected in the products of combustion for varying per cents of excess air as determined by the Orsat or CO_2 records, from which we work back to regulate for the proper air supply.

From this data we can complete a hypothetical heat balance for any plant in terms of gas per boiler horsepower or, if plant water rate is known, the cubic feet of gas per kw-hr.

Knowing the constituents of the gas, i.e. carbon, hydrogen, etc., content as given in Table 4, and with our flue gas analyses complete (accurate sampling), the flue gas temperatures known, feed water temperature, degrees superheat and steam pressure, we may quite accurately compute boiler performance and efficiencies from the known losses with "radiation and unaccounted" assumed. This would virtually be substituting known figures in the hypothetical heat balance.

The various formulas for determining these losses are as follows:

Weight of dry products per pound of gas burned would be—

$$W = \frac{11\,CO_2 + 8O_2 + 7\,(N_2 + CO)}{3\,(CO_2 + CO)} \times \left(C + \frac{S}{1.833}\right)$$

where CO_2, O_2, N_2 and CO are percentages *by volume* as shown in flue gas analyses, and C and S the carbon and sulphur contents *by weight* from the ultimate analysis of the fuel.

Substituting flue gas analyses shown under 15 per cent excess air in hypothetical heat balance, we have for the weight of the dry product—

$$W = \frac{(11 + 10.03) + (8 \times 2.97) + 7\,(87 + .03)}{3\,(10.03 + .03)} \times .6605 =$$

16.261 lb.

It will be noted that this checks very closely with the tabulation of weights of products under 15 per cent excess air, they being 18.146 lb. less 1.93 lb. of H_2O or 16.216 lb. The .03 per cent of CO was used in formula for illustration where it does not show in tabulation and accounts for the slight difference in formula computation.

Loss due to burning of hydrogen would be—

$$L = 9 \times H_2\,[(212 - t) + 970.4 + .48\,(T - 212)]$$

Loss due to heat in dry chimney gases would be—

$$L = W \times .24\,(T\text{-}t)$$

Loss due to incomplete combustion would be—

$$L = \frac{CO}{CO_2 + CO} \times C$$

Loss due to moisture in the air would be—

$$L = w \times .48\,(T - t)$$

Where H_2 = per cent of hydrogen (ultimate analysis)

T = temperature of escaping gases

t = room temperature or inlet air

C = per cent of carbon by wt. (ultimate analysis)

W = Weight of dry products of combustion, lb.

w = Weight of moisture in air, lb.

The results given in the foregoing setup are obtainable without economizers, superheaters or air heaters, provided, of course, the following other essentials of complete combustion are considered, viz:

Proper amount of air (oxygen) supplied
Proper mixtures of gas and air
Proper mixtures at proper place (early ignition)
Sufficient space for mixture and for volume of gases created
Sufficient time for complete combustion before cooling surfaces of vessel are encountered.
Sufficient temperatures (functions of above)
Proper distribution of heat of combustion (baffles)

These essentials to complete combustion and high percentages of efficiency bring up the point of proper furnace design and burners. Without going into the details of furnace design, let it be said that a large clear furnace space with no checker work nor obstructions is a prime requisite.

Combustion space should be 1½ to 2 cu. ft. per developed horsepower of the boiler or as close to this as is possible. A 500 hp. boiler, to be operated at 300 per cent of capacity or 1500 hp., should have from 2250 to 3000 cu. ft. of combustion space and this space should be in proper relation to the heating surface.

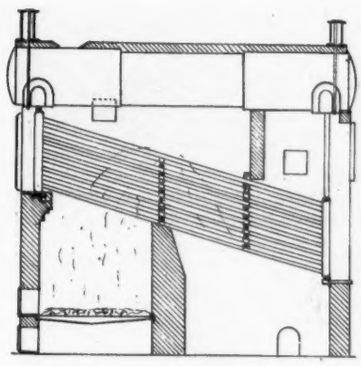
All boilers, with the exception of one or two recent developments, were designed originally to burn coal on grates and no changes have been made for gas, oil or powdered fuel. There was a definite relationship between water flow or circulation and heat application and flow. This relationship should be considered when changing from solid to liquid, gaseous or powdered fuels, and is probably best illustrated by the sketches shown in Fig. 5.

Hollow walls and floors and return of all available waste heat for hot air, which should be in all cases introduced through the burners if possible, are factors that should be considered in gas fired furnaces for better efficiencies and high ratings.

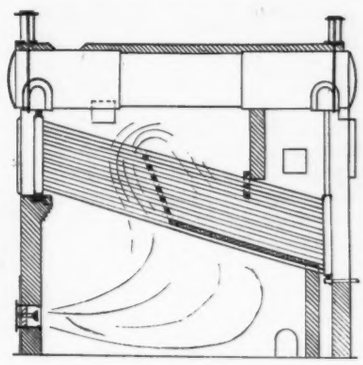
The burners are usually placed in a sheet metal front box and the hot air collected here and introduced through the burners as partially shown in sketch 7.

Burners

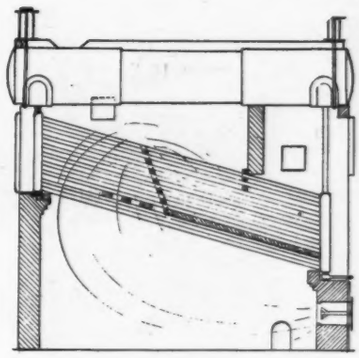
There are so many types and makes of gas burners on the market, all with more or less merit if



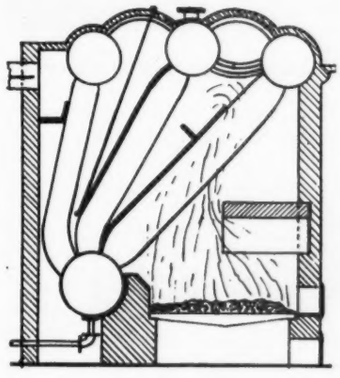
Sketch 1



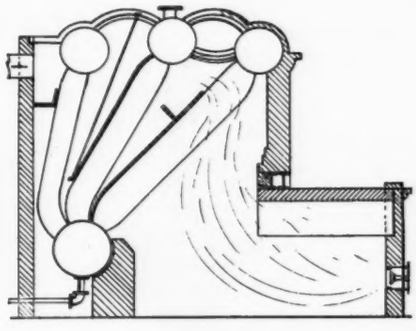
Sketch 2



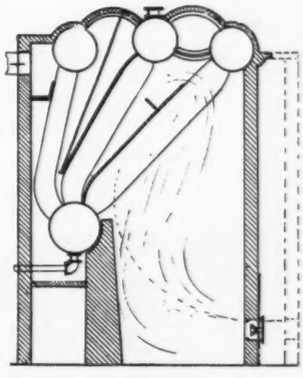
Sketch 3



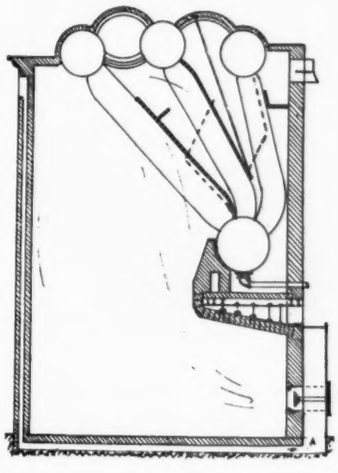
Sketch 4



Sketch 5



Sketch 6



Sketch 7

Sketch No. 1 shows a vertically baffled boiler as originally designed for coal burning with heat application at high end of tubes. Obviously, the combustion space is too small for any fuel and at the present time, even with coal as fuel, this boiler would be raised considerably to gain combustion space.

The usual method of rebaffling this boiler for oil or gas would be to remove the bridge wall and baffle as shown in sketch No. 2. As will be noticed, the point of greatest heat is now located at the lower end of the tubes.

The proper way to fire this boiler would be from the rear as shown in sketch No. 3 with clear open space and better heat distribution and hot point at upper end of tubes.

Sketch No. 4 shows bent tube type of boiler as originally designed for coal burning with insufficient combustion space for any fuel.

Sketch No. 5 shows the same boiler with combustion space increased by a dutch oven extension but this gives a poor heat distribution and application.

Sketch No. 6 shows the boiler raised for increased combustion space, but it will be noticed that space is still restricted and heat application at top of tubes. The front of the boiler should have been extended as shown by dotted lines, giving more space and better heat application.

Sketch No. 7 shows this boiler raised, front extended and fired from rear with suspended arch under the mud drum. This gives a large clear space and proper heat application and distribution.

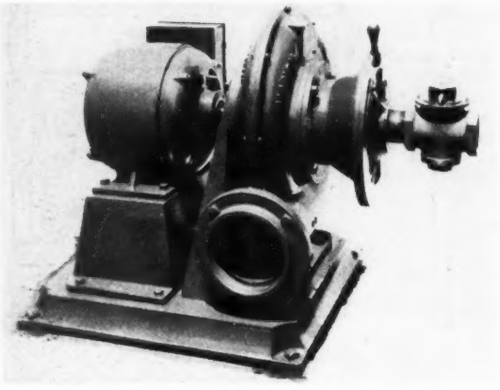
Fig. 5—Sketches showing how coal-fired boiler furnaces may be revamped for firing with liquid or gaseous fuels.

properly applied to fit the required conditions, that the selection may be one of choice depending on—

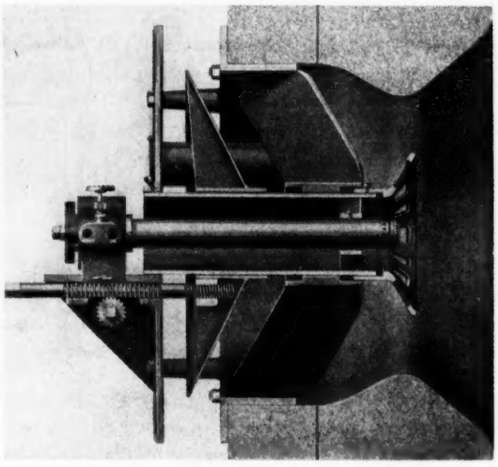
Delivery pressures of gas at source of use
Adaptability of size and shape to furnace requirements
Mechanical details of construction
Desired capacities
Air and gas control
Mixing features
Adaptability to use one or more fuels with same burner

Burners may be divided into approximately three main classes, as follows:

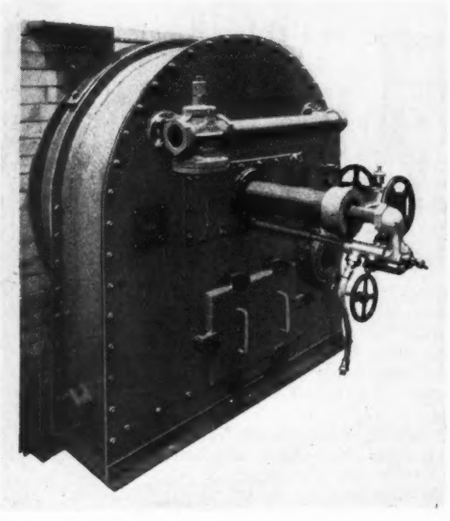
(1) Low pressure, where gas is delivered in terms of ounces or inches of water up to 2 or 3 pounds,—multi-jet type and barrel type.



Pre-mix burner, mechanical mixture type.



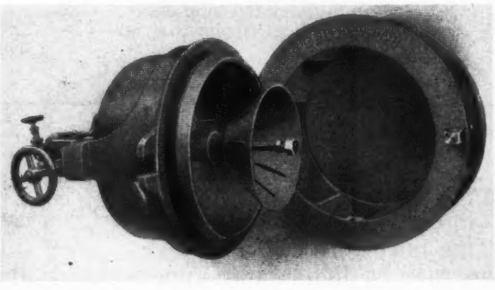
Register type combination gas and oil burner.



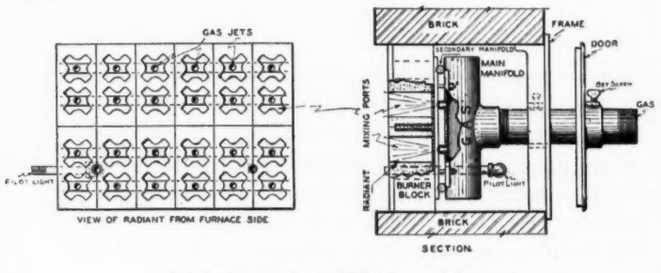
Mechanical oil burner with gas connection.

Pre-mix burner, natural draft.

Barrel type, low pressure pre-mix burner.



Register type oil burner, convertible to gas burner by change of burners.



Low pressure, multi-jet gas burner.

Fig. 6—Various types of gas and combined oil and gas burners.

(2) High pressure, where gas is delivered in terms of pounds, say 5 to 50, or more. The type used in this class is usually the register type with central burner and surrounding air vanes for mixing air and gas. This type is now made to burn gas, oil or powdered fuel through the same register with no change of burners.

(3) Pre-mix burners, where gas and air are mixed before entering furnace.

The limiting factors in all burners are the gas pressure and size of burner opening for gas supply, the available furnace draft (dependent on stack or induced draft fan), the size of openings for air supply and the arrangement for obtaining a proper mixture as quickly as possible.

Low pressure burners are best adapted to small boilers and moderate capacities, although some large installations have been made with them. Mixtures are inclined to be late and there is considerable flame, especially when crowding. This may be corrected to some extent by the admission of secondary air through an independent source, provided a proper mixture may be obtained, but this is usually hard to do. *Side wall air admission does not mix.* Where hollow floors are used, ports up through the floor immediately in front of the burner will help. The air openings and jets of the multi-jet burners being small and numerous for high capacities, necessitate considerable space.

High pressure and register type burners are best adapted to modern boilers where varied capacities from high to low, high efficiencies and general flexibility are required. They are well adapted to forced draft or natural draft to almost any kind of construction, return heat from walls or air heaters, and to quick changes to oil or powered fuel.

The high velocity of the high-pressure gas aids air supply with ejector effect, and the air vanes of the register, with whirling effect of the air, make a quick and turbulent mixture. Furnaces with this type of burner are usually free from any flame, "clear as a bell" even when operating with very low excess air.

Pre-mix burners are especially adapted to boilers with lack of draft and combustion space, and to industrial furnaces. Complete combustion really takes place at the outlet nozzle. Proper capacities must be selected in the beginning as they are limited in both gas and air supply to the inlet nozzles.

The illustrations in Fig. 6 show different types of burners.

Gas Measurements

The proper measurement of gas and the proper corrections for given conditions are all important factors in the economical use of gas for fuel.

The orifice meter is quite universally used for measuring gas to power plants and records in terms of static pressure, pounds and differential in inches of water. Hourly averages of the pen readings of the static and differential are made either by planimeter or by observation methods, and it is claimed that the latter are more accurate because of slippage on backward movements of the planimeter.

The quantity of gas is computed from these readings by the formula—

$$Q = \sqrt{} C\ hP$$

Where Q = Quantity of gas, cu. ft.
h = Average differential in.
P = Average absolute static pressure, lb. or P + barometric pressure
C = Constant for the given orifice

A book of extensions for the computation of $\sqrt{}hP$ usually accompanies the meter installation, so it is only necessary to find extension for the given averages and multiply by the orifice constant. Operators usually do not have this book available and cannot make the full computations, but they can easily learn how to average the differential and pressure, and graphs can be made, similar to Fig. 7, within the range of daily operation that will give direct readings for hourly fuel consumption for the station log.

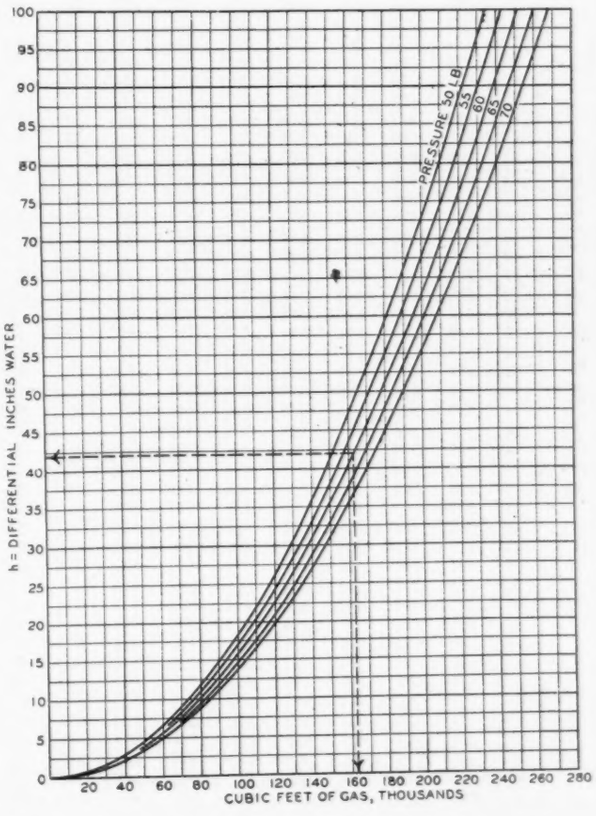


Fig. 7—Direct reading chart for recording orifice meter at various static and differential pressures, Concho Station, West Texas Utilities Company. (Orifice constant—2913.4).

The standard for gas measurements is 60 deg. fahr. temperature and 30 in. of mercury.

A table of temperature and pressure corrections published by the American Meter Company, is given in Table 5. It will be noted that in the case of a gas temperature of 72 deg. and a barometer of 29 in., the correction factor is .935. This, applied to one million cubic feet of gas, amounts to 935,000 cu. ft. This, at a price of 20c per M cubic

TABLE 5

CORRECTION FACTORS FOR TEMPERATURE AND PRESSURE

BASED ON GAS SATURATED WITH AQUEOUS VAPOR

AMERICAN METER COMPANY, INC., NEW YORK

TEMPERATURE	BAROMETER																			
F°	28.6	28.7	28.8	28.9	29.0	29.1	29. 2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5
107	.816	.820	.823	.826	.829	.832	.835	.838	.841	.844	.847	.851	.854	.857	.860	.864	.867	.870	.874	.877
106	.820	.823	.826	.829	.832	.835	.838	.841	.844	.847	.851	.854	.857	.860	.863	.867	.870	874	.878	.881
105	.823	.827	.830	.833	.836	.839	.842	.845	.848	.851	.855	.858	.861	.864	.867	.871	.874	.878	.881	.884
104	.827	.830	.833	.836	.839	.842	.845	.848	.851	.854	.858	.861	.864	.867	.871	.874	.878	.881	.884	.887
103	.830	.834	.837	.840	.843	.847	.849	.852	.855	.858	.862	.865	.868	.871	.874	.878	.881	.885	.888	.891
102	.834	.837	.840	.843	.847	.850	.853	.856	.859	.862	.865	.868	.871	.874	.878	.881	.885	.888	.891	.894
101	.837	.840	.843	.846	.850	.853	.856	.859	.862	.865	.868	.872	.875	.878	.882	.885	.888	.891	.895	.898
100	.840	.843	.846	.849	.853	.856	.859	.862	.865	.868	.872	.875	.878	.881	.885	.888	.891	.895	.898	.901
99	.844	.847	.850	.853	.857	.860	.863	.866	.869	.872	.876	.879	.882	.885	.889	.892	.895	.898	.902	.905
98	.847	.850	.853	.856	.860	.863	.866	.869	.872	.875	.879	.882	.885	.888	.892	.895	.898	.902	.905	.908
97	.850	.853	.856	.859	.863	.866	.870	.873	.876	.879	.882	.885	.888	.891	.894	.898	.901	.905	.908	.911
96	.854	.857	.860	.863	.867	.870	.873	.876	.879	.882	.886	.889	.892	.895	.898	.901	.904	.908	.911	.914
95	.857	.860	.863	.866	.870	.873	.876	.879	.882	.885	.889	.892	.895	.898	.901	.904	.908	.911	.914	.918
94	.860	.863	.866	.869	.873	.876	.879	.882	.885	.888	.892	.895	.898	.901	.904	.907	.911	.914	.918	.921
93	.863	.866	.869	.872	.876	.879	.883	.886	.889	.891	.895	.898	.901	.904	.907	.910	.914	.918	.921	.924
92	.866	.869	.872	.875	.879	.882	.885	.889	.892	.894	.898	.902	.904	.907	.910	.914	.917	.921	.924	.928
91	.869	.872	.875	.879	.882	.885	.889	.892	.895	.898	.902	.905	.908	.911	.914	.917	.921	.924	.928	.931
90	.872	.875	.878	.881	.885	.888	.892	.895	.898	.901	.905	.908	.911	.914	.917	.920	.924	.927	.931	.934
89	.875	.878	.882	.885	.889	.892	.895	.893	.901	.904	.907	.910	.914	.917	.920	.923	.927	.931	.934	.937
88	.878	.881	.885	.888	.892	895	.898	.901	.904	.907	.910	.913	.917	.920	.923	.926	.930	.934	.937	.940
87	.881	.884	.888	.891	.895	.898	.901	.904	.907	.910	.913	.916	.920	.923	.926	.929	.933	.937	.940	.943
86	.884	.887	.890	.894	.898	.901	.904	.907	.910	.913	.916	.919	.923	.926	.929	.932	.936	.940	.943	.946
85	.887	.890	.893	.896	.900	.903	.906	.909	.913	.916	.919	.922	.926	.929	.932	.936	.939	.943	.946	.949
84	.889	.893	.896	.899	.903	.906	.909	.912	.915	.919	.922	.925	.928	.932	.935	.939	.942	.946	.949	.952
83	.892	.895	.899	.902	.906	.909	.912	.915	.918	.921	.924	.928	.931	.935	.938	.942	.945	.949	.952	.955
82	.895	.898	.901	.905	.908	.911	.914	.918	.921	.924	.927	.931	.934	.937	.941	.945	.948	.951	.954	.958
81	.898	.901	.905	.908	.911	.914	.917	.921	.924	.927	.930	.934	.937	.940	.944	.948	.951	.954	.957	.960
80	.901	.904	.907	.910	.914	.917	.920	.923	.927	.930	.933	.937	.940	.943	.946	.950	.954	.957	.960	.963
79	.904	.907	.910	.914	.917	.920	.923	.926	.930	.933	.936	.939	.943	.946	.949	.953	.956	.960	.963	.967
78	.906	.909	.913	.916	.919	.923	.926	.929	.932	.936	.939	.942	.946	.949	.952	.956	.959	.962	.966	.969
77	.909	.912	.915	.919	.922	.925	.928	.931	.935	.938	.942	.945	.948	.951	.955	.953	.962	.965	.968	.972
76	.911	.915	.918	.921	.925	.928	.931	.935	.938	.941	.944	.948	.951	.954	.958	.961	.964	.968	.971	.975
75	.914	.917	.921	.924	.928	.931	.934	.937	.940	.943	.947	.950	.954	.957	.960	.963	.967	.971	.974	.978
74	.917	.920	.924	.927	.930	.933	.937	.940	.943	.947	.950	.953	.957	.960	.963	.966	.970	.973	.977	.980
73	.920	.923	.926	.930	.933	.936	.940	.943	.946	.949	.953	.956	.960	.963	.966	.969	.972	.976	.980	.983
72	.922	.925	.929	.932	.935	.939	.942	.945	.949	.952	.955	.953	.962	.965	.968	.972	.975	.979	.982	.986
71	.925	.928	.931	.935	.938	.941	.945	.948	.951	.954	.958	.961	.965	.968	.971	.975	.978	.981	.985	.989
70	.927	.931	.934	.937	.941	.944	.947	.950	.954	.957	.960	.964	.967	.970	.974	.977	.980	.984	.988	.991
69	.930	.933	.937	.940	.944	.947	.950	.953	.957	.960	.963	.967	.970	.973	.977	.980	.983	.987	.990	.994
68	.932	.936	.939	.942	.946	.949	.952	.956	.959	.962	.966	.969	.972	.976	.979	.983	.986	.989	.993	.997
67	.935	.938	.942	.945	.949	.952	.955	.959	.962	.965	.968	.972	.975	.979	.982	.985	.989	.992	.996	1.000
66	.938	.941	.944	.948	.951	.954	.958	.961	.964	.968	.971	.974	.978	.981	.985	.989	.992	.995	.998	1.002
65	.941	.944	.947	.950	.954	.957	.960	.963	.967	.970	.973	.977	.980	.984	.987	.991	.994	.997	1.001	1.005
64	.943	.946	.949	.953	.956	.959	.963	.966	.969	.973	.976	.980	.993	.986	.990	.994	.997	1.000	1.004	1.008
63	.945	.949	.952	.955	.959	.962	.965	.969	.972	.975	.979	.982	.985	.989	.993	.996	1.000	1.003	1.006	1.010
62	.947	.951	.954	.958	.961	.964	.968	.971	.975	.978	.981	.985	.988	.991	.995	.999	1.002	1.005	1.009	1.013
61	.950	.954	.957	.961	.964	.967	.971	.974	.977	.981	.984	.987	.991	.994	.998	1.001	1.005	1.008	1.011	1.015
60	.952	.956	.959	.963	.966	.969	.973	.976	.980	.983	.986	.990	.993	.997	1.000	1.004	1.007	1.010	1.014	1.017
59	.955	.959	.962	.965	.969	.972	.976	.979	.983	.986	.989	.992	.995	.999	1.003	1.006	1.010	1.013	1.016	1.020
58	.957	.961	.964	.968	.971	.975	.978	.981	.985	.988	.992	.995	.999	1.002	1.005	1.009	1.012	1.016	1.019	1.023
57	.960	.963	.967	.970	.974	.977	.980	.984	.988	.991	.994	.997	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025
56	.962	.966	.969	.973	.976	.979	.982	.986	.990	.993	.996	1.000	1.003	1.007	1.010	1.014	1.017	1.021	1.024	1.028
55	.965	.968	.972	.975	.979	.982	.985	.989	.993	.996	.999	1.002	1.006	1.009	1.013	1.016	1.020	1.023	1.027	1.030
54	.967	.970	.974	.977	.981	.984	.988	.991	.995	.998	1.001	1.005	1.008	1.012	1.015	1.019	1.022	1.026	1.029	1.033
53	.969	.973	.976	.980	.983	.986	.990	.993	.997	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025	1.028	1.031	1.035
52	.971	.975	.978	.982	.985	.989	.992	.996	.999	1.003	1.006	1.010	1.013	1.017	1.020	1.024	1.027	1.031	1.034	1.038
51	.974	.977	.981	.984	.988	.991	.995	.998	1.002	1.005	1.009	1.012	1.016	1.019	1.023	1.026	1.030	1.033	1.037	1.040
50	.976	.980	.983	.987	.990	.994	.997	1.001	1.004	1.008	1.011	1.015	1.018	1.022	1.025	1.029	1.032	1.036	1.039	1.043
49	.979	.982	.986	.989	.993	.996	1.000	1.003	1.007	1.010	1.014	1.017	1.021	1.024	1.028	1.031	1.035	1.038	1.042	1.045
48	.981	.985	.988	.992	.995	.999	1.002	1.006	1.009	1.013	1.016	1.020	1.023	1.027	1.030	1.034	1.037	1.041	1.044	1.048
47	.984	.987	.991	.994	.998	1.001	1.005	1.009	1.012	1.015	1.019	1.022	1.026	1.029	1.033	1.036	1.040	1.043	1.047	1.050
46	.986	.990	.993	.997	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025	1.028	1.032	1.035	1.039	1.042	1.046	1.049	1.053
45	.989	.992	.996	.999	1.003	1.006	1.010	1.013	1.017	1.020	1.024	1.027	1.031	1.034	1.039	1.041	1.045	1.048	1.052	1.056
44	.991	.994	.998	1.001	1.005	1.008	1.012	1.015	1.019	1.022	1.026	1.029	1.033	1.036	1.040	1.043	1.047	1.050	1.054	1.059
43	.993	.997	1.001	1.004	1.008	1.011	1.015	1.018	1.022	1.025	1.029	1.032	1.036	1.039	1.043	1.046	1.050	1.053	1.057	1.060
42	.995	.999	1.003	1.006	1.010	1.013	1.017	1.020	1.024	1.027	1.031	1.034	1.038	1.041	1.045	1.048	1.052	1.055	1.059	1.063
41	.998	1.001	1.005	1.009	1.012	1.016	1.019	1.023	1.026	1.030	1.034	1.037	1.041	1.044	1.048	1.051	1.055	1.058	1.062	1.066
40	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025	1.028	1.032	1.036	1.039	1.043	1.046	1.050	1.053	1.057	1.060	1.064	1.068
39	1.002	1.006	1.010	1.013	1.017	1.020	1.024	1.028	1.031	1.035	1.038	1.042	1.045	1.049	1.052	1.056	1.059	1.063	1.066	1.070

Observed volume multiplied by factor corresponding to observed temperature and barometric pressure equals corrected volume.

feet, would amount to $187.00. It is, therefore, important that records of barometer and the temperature of the gas, as metered, should be kept.

A formula for this correction factor would be—

$$V2 = V1 \times \frac{60 + 460}{T + 460} \times \frac{\text{Barometer} + \text{Pressure (in. Hg.)}}{30.0}$$

Where V2 = Corrected volume
V1 = Volume as metered
T = Temperature recorded
P = Pressure in inches of mercury

Effect of Moisture in the Air and Moisture in the Gas

Moisture in the air reduces the amount of oxygen in the air available for combustion and also reduces the flame temperature.

Moisture in the gas has the same effect as moisture in any other fuel, requiring heat to break it up into oxygen and hydrogen.

All fuels containing hydrogen, produce water vapor on combustion, yielding heat on condensation. This latent heat of vaporization for the conversion of *water to steam* is liberated on the condensation of *steam to water;* therefore, it only becomes available when the flue products are cooled to such a temperature that the water actually condenses. Natural gas has large percentages of hydrogen, as compared with oil and coal, and this combined with moisture in the gas, makes the "loss due to burning hydrogen" excessive.

However, as gas is metered "wet" and burned "wet," this factor of correction is seldom applied, but the question arises, when computing efficiencies as compared with coal which are based on water from and at 212 deg. per lb. of dry coal, whether or not this factor should be considered. Following are correction factors.

The correction factor for air to standard conditions of 62 deg. fahr. and 29.92 in. Hg., is—

$$(1) \qquad C = \frac{T + 62}{T + t'} \times \frac{P}{29.92}$$

This same factor, considering moisture content of air, becomes—

$$(2) \qquad C = \frac{T + 61}{T + t'} \times \frac{P - (Vp^1 \times Vp^2)}{29.92}$$ where:

T = Absolute temperature
t' = Observed temperature
P = Barometric pressure, in. Hg.
Vp^1 = Vapor pressure, in. Hg. at t' deg.
Vp^2 = Vp^1 × per cent of saturation

$$\text{Per cent of saturation is } \frac{\text{Grains of Moisture in air at t' deg.}}{\text{Grains of Moisture, full saturation @ t' deg.}}$$

The difference between (1) and (2) gives per cent correction for moisture.

The above formula applied to gas, the standard of measurement being 60 deg. fahr. and 30 in. Hg., becomes, without considering moisture or vapor pressure—

$$(3) \qquad C = \frac{T + 60}{T + t'} \times \frac{P + p}{30}$$

Considering moisture of gas, the formula becomes—

$$(4) \quad C = \frac{T + 60}{T + t'} \times \frac{P + p - (Vp^1 \times Vp^2)}{30}$$ where:

T = Absolute temperature
t' = Temperature of gas
P = Barometric pressure, in. Hg.
p = Gas pressure, in. Hg.
Vp^1 = Vapor pressure, in. Hg. at t' deg.
Vp^2 = Vp^1 × per cent of saturation.

$$\text{Per cent of saturation is } \frac{\text{Grains of Moisture in gas at t' deg.}}{\text{Grains of Moisture, full saturation @ t' deg.}}$$

The difference between (3) and (4) gives per cent correction for moisture in the gas.

Natural gas is one of the safest fuels to use, if properly handled. All joints, connections and equipment, such as regulators, meters, etc., must be perfectly tight and kept tight both for safety and economy.

Gas cocks should be placed between the header and the burner valves as the valves sometimes leak. These cocks must be closed when the boiler is not in use. Dampers must be opened or induced draft fan started for a few minutes before lighting a fire. Each burner on a cold boiler should be lighted separately with a torch or lighter.

Where several burners are used, the best method of control is with a master valve. The burner valves are operated wide open and variations of load are taken up by use of the master valve controlling pressure to all valves. Close to the master valve control of each boiler should be a gas pressure gage in plain sight, easily readable, so pressures for varying loads may be observed.

A positive damper control of the worm and gear type on the main damper of the boiler, should be installed, and immediately in front of it should be an accurate draft gage so that variations of 1/100 of an inch of water gage can be made. If these two are close to the master gas valve, immediate and very accurate control may be obtained.

The matter of accurate and positive damper control is very essential. Where electric-driven induced draft fans are used, there is usually much too wide a range of draft between rheostat points of the control, and the damper is necessary.

Variations of 1/100 of an inch of water gage in furnace drafts sometimes spell the difference between CO and lack of CO in the gases where highest CO_2 obtainable is being sought, and no gas fired boiler should be operated without CO_2 instruments, recording preferred.

After a boiler has been slowly brought on the

line, we must make adjustments for CO_2. The best way is to make tabulation. For illustration we will make the assumptions given in Table 6.

These figures are all assumed but demonstrate the point. In the last figures given we are back of our .20-in. furnace draft, less gas consumption,

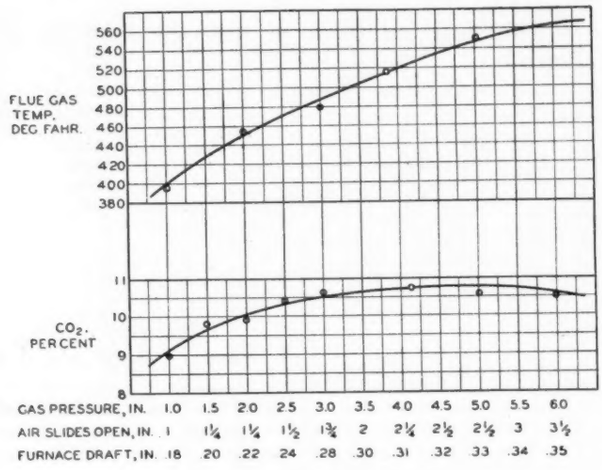


Fig. 8—Operating Chart

(Note: When steam requirements need 4 in. gas pressure, set air slides about 2½ in. and draft gage at .31 in. Stack temperature and CO_2 should be about as indicated on curves for best results. Other pressures accordingly.

Hazy fire, flame or fluttering indicates insufficient air.

Temperatures in excess of those indicated usually mean excess air, dirty boiler or leaky baffles.

Figures indicated are not rigid nor infallible.. Frequent checks with hand analyzer should be made. Points on curves are averages of many checks on clean boiler, are substantially correct and given as a guide for setting the draft and air slides for various gas pressures.)

highest CO_2 and steam, as before. The same results could be obtained by closing the damper but in all probability the furnace draft would have been, say .08 in. and much less velocity and poorer mixture.

When high CO_2 is reached, tests for oxygen and CO must accompany. CO_2 depends on carbon content of gas, and with some gases, 9.6 per cent might be the high limit.

In making adjustments for proper operation, only make one change at a time, record the results, make another, and compare.

There should be no flame, haze or smoke in the furnace; it should be perfectly clear with a blue zone in front of the burners. There will be no noticeable change in furnace conditions with low CO_2 and high excess air, as against high CO_2 and proper air. Could temperatures be recorded, however, there would be a considerable change in favor of the high CO_2. It has been noticed also that high percentages of monoxide in the flue gases, may be obtained with burners that have an early and proper mixture with no apparent change in furnace conditions, i.e. no smoke or haze.

The inability to tell from observation what is occurring in a gas fired furnace shows the importance of CO_2 records. Where only a hand analyzer is available, tabulations like the preceding can be made and posted or plotted, showing just what number of burners, air slide openings, gas pressure and furnace draft for certain loads will produce the highest CO_2 and operators can follow to good advantage.

In the matter of drafts in gas burning it must be remembered that drafts determine the air supply and the mixing effect. Some prefer low drafts or nearly a balanced draft condition in the furnace. The writer prefers high draft conditions, especially since we are now keeping walls tight and using lots of hollow wall construction so that the objection of greater infiltration of air is eliminated or nearly so.

TABLE 6

Time	Steam Pressure Lb.	Steam Flow Lb. or hp.	Gas Pressure Lb.	Furnace Draft	Air Slides Open	Number of Burners	Per Cents CO_2	O_2	CO
9:30	250	30,000	10	.30″	Full	5	8		
9:45	250	30,000	10	.25″	Full	5	8.5		
10:00	250	30,000	10	.20″	Full	5	9		

It will be noted that we have increased CO_2 by lowering furnace draft, and inasmuch as we desire to maintain high velocity through the burner for the good mixing effect and still increase our CO_2, we cannot close damper further, so the air slides are closed partially. Now continue the tabulation. Note furnace draft increases.

Time	Steam Pressure Lb.	Steam Flow Lb. or hp.	Gas Pressure Lb.	Furnace Draft	Air Slides Open	Number of Burners	Per Cents CO_2	O_2	CO
10:15	250	30,000	10	.25″	¾ open	5	9		

We are getting the same amount of air at a higher velocity through the burners but CO_2 has not increased. Now close the damper for lower furnace draft.

Time	Steam Pressure Lb.	Steam Flow Lb. or hp.	Gas Pressure Lb.	Furnace Draft	Air Slides Open	Number of Burners	Per Cents CO_2	O_2	CO
10:30	250	30,000	10	.23″	¾ open	5	10		

Note increase of CO_2 and probably steam rising, so gas pressure must be reduced, assuming constant load.

Time	Steam Pressure Lb.	Steam Flow Lb. or hp.	Gas Pressure Lb.	Furnace Draft	Air Slides Open	Number of Burners	Per Cents CO_2	O_2	CO
10:45	255	30,000	9	.23″	¾ open	5	9.5		

Decrease of gas and the same amount of air lowers the CO_2, so close the damper slightly for draft reduction.

Time	Steam Pressure Lb.	Steam Flow Lb. or hp.	Gas Pressure Lb.	Furnace Draft	Air Slides Open	Number of Burners	Per Cents CO_2	O_2	CO
11:00	250	30,000	9	.20″	¾ open	5	10.3	3.0	0.0

The matter resolves itself into that of a given quantity of air through a larger opening at low velocity or the same amount of air through a smaller opening at a high velocity.

Air slides are provided on all gas burners so that

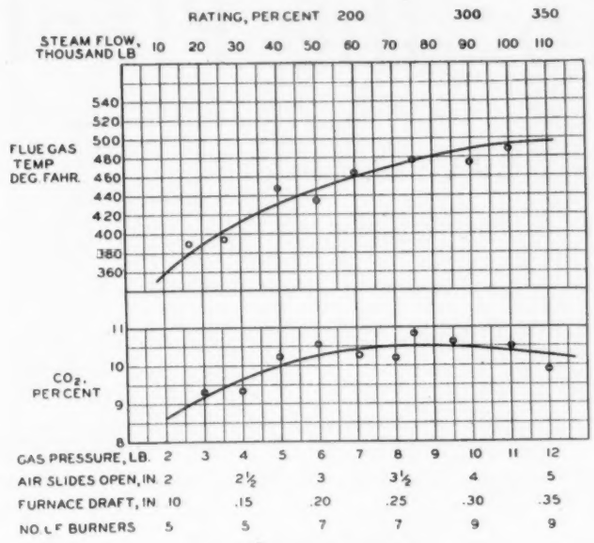

RATING, PER CENT 200 300 350
STEAM FLOW, THOUSAND LB 10 20 30 40 50 60 70 80 90 100 110
FLUE GAS TEMP DEG. FAHR.
540 520 500 480 460 440 420 400 380 360
CO_2, PER CENT
11 10 9 8
GAS PRESSURE, LB. 2 3 4 5 6 7 8 9 10 11 12
AIR SLIDES OPEN, IN. 2 2½ 3 3½ 4 5
FURNACE DRAFT, IN. 10 .15 .20 .25 .30 .35
NO. OF BURNERS 5 5 7 7 9 9

Fig. 9—Operating Chart

(Example: If steam flow indicates 5000 lb. per hr. you need 6 lb. gas pressure, 3 in. opening of air slides and .20 in. on draft gage. Other rates in accordance. CO_2 and stack temperature should then be about as indicated on curves. Stack temperature rises indicate excess air, dirty boiler, leaky baffles.

either way may be used according to conditions, results and preferences.

The writer has obtained high efficiencies with both methods and prefers the high velocities on account of the better mixing effects.

The accompanying charts, Figs. 8 and 9, show such tabulations for a small plant with a low pressure multi-jet gas burner but not equipped with a steam flow meter or CO_2 recorder, and one for high pressure burner where steam flow meter was available. Results were surprisingly good as compared to previous practice.

Fuel Selection

The choice of a fuel in power plants is all a matter of price and adaptability, and usually price wins.

To compare the evaporative costs for different fuels, the accompanying chart, Fig. 10, is convenient, and the efficiencies from which the costs are computed are based on a wide range of plant practice in some thirty states.

Actual evaporative costs (from and at 212 deg.) are given, and to compare gas with coal there must be added to the ton price the cost of handling coal and ash, soot blowing, power for pulverization and stokers. To oil must be added the cost of handling from cars to tanks, heating, pumping and atomizing where steam atomizers are used. Extra labor is an important item.

The matter of cleanliness and convenience of natural gas over any other fuel and such facts as no storage equipment, no expensive coal handling equipment, no pumping, electric or steam consumption, no air pollution, little if any soot and soot blowing expenses, with many other items in its favor, makes it a fuel for which power plant operators should be glad to pay a bonus.

One of the greatest factors, especially for the utilities, where continuity of service is paramount, is that two or even three fuels are usable in the same furnace and with the same equipment, as far as burning is concerned.

For many years they were at the mercy of the

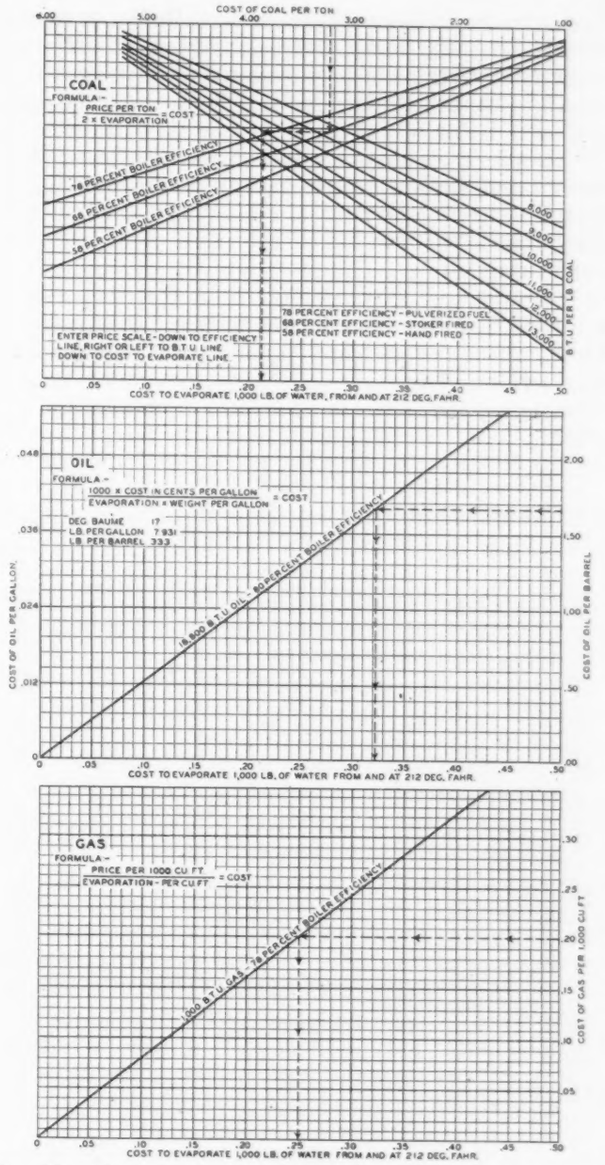

COST OF COAL PER TON
COAL
FORMULA –
PRICE PER TON / 2 × EVAPORATION = COST
78 PERCENT BOILER EFFICIENCY
68 PERCENT BOILER EFFICIENCY
58 PERCENT BOILER EFFICIENCY
78 PERCENT EFFICIENCY – PULVERIZED FUEL
68 PERCENT EFFICIENCY – STOKER FIRED
58 PERCENT EFFICIENCY – HAND FIRED
ENTER PRICE SCALE – DOWN TO EFFICIENCY LINE, RIGHT OR LEFT TO B T U LINE, DOWN TO COST TO EVAPORATE LINE
B T U PER LB COAL
COST TO EVAPORATE 1,000 LB. OF WATER, FROM AND AT 212 DEG. FAHR.
OIL
FORMULA –
1000 × COST IN CENTS PER GALLON / EVAPORATION × WEIGHT PER GALLON = COST
DEG. BAUME 17
LB. PER GALLON 7.931
LB. PER BARREL 333
18,000 B.T.U. OIL – 80 PERCENT BOILER EFFICIENCY
COST OF OIL PER GALLON
COST OF OIL PER BARREL
COST TO EVAPORATE 1,000 LB. OF WATER FROM AND AT 212 DEG. FAHR.
GAS
FORMULA –
PRICE PER 1000 CU. FT. / EVAPORATION – PER CU. FT. = COST
1000 B.T.U. GAS – 78 PERCENT BOILER EFFICIENCY
COST OF GAS PER 1,000 CU. FT.
COST TO EVAPORATE 1,000 LB. OF WATER FROM AND AT 212 DEG. FAHR.

Fig. 10—Chart showing evaporative costs for coal, oil and gas.

coal operators, not only as to price, but on account of strikes, wrecks and weather, and many is the gray head, dimming eye and wrinkled forehead, caused by waiting for a car of coal and having to keep the old plant turning over, that hails with delight the advent of a general distribution of natural gas throughout the country.

An Equipment Record for the Plant

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Southwestern Public Service Co.

Amarillo, Texas

The keeping of proper equipment records should be a routine job in every plant. Once a suitable system is established, it is neither difficult nor costly to maintain it. On the other hand, the neglect of such records may result in serious losses due to forced interruption of plant operation and excessive repair and replacement charges . . . . The author describes a simple but adequate record system which, with such detailed modifications as may seem advisable in individual cases, may be adapted to any plant.

IN the operation of the average plant, the engineer in charge is often confronted with the problem of devising and maintaining a system of accurate records covering the performance or history of the equipment under his charge. These records must not only be as complete as possible, but must also be simple and easy of operation. Further, they must be of such a nature that they will be of continual value in the care of the equipment in question, instead of serving merely as a record of past performance.

A simple and convenient system comprising such a record together with means of keeping it, whereby the above features are considered, is described in this article. The system comprises a *record, inventory, equipment, tickler file* and a *memorandum form.*

The Record

The *record* consists of a book made up of a stiff-back, loose-leaf binder, such as will permit of easy insertion and removal of slips containing the necessary data and which can be opened for working position by means of a small lever. Such a book filled with slips, is shown in Fig. 1.

The cover may be, of course, of almost any size, depending upon the necessary amount of data to be entered; the one shown herewith, however, is 11 x 19 in. with finger spacing such that slips with eight holes per 3⅛ in. width are accommodated. The slips are 8½ in. in length. This arrangement permits the shifting of the slips as becomes necessary when more data is filed under the same heading, and permits each slip to be held by no less than four fingers at any time.

The form devised for the slips used is illustrated by the close-up view of the book (Fig. 2) and has been found to be of advantage over other forms in that the data is presented in a graphic manner, which serves to indicate at a glance the interval between repairs, inspections, breakdowns, etc.

Each slip is designed to cover a period of one year, the months being listed as the ordinates and the days of the month as the abscissa. The year is indicated at the top of the slip while the particular job (repair, inspection, etc.) is listed below and, as shown, follows definite headings as indicated by the amount of indention.

In the extreme lower right hand corner, the job number is entered. This number conforms to the indexing system as shown in the plant inventory, which is kept in a separate book and covers all plant equipment. The purpose of numbering each slip is to permit of quick and easy identification, the necessity of which will be explained.

The Inventory

The *inventory,* three pages of which are illustrated in Fig. 3, is contained in a loose-leaf flexible cover, taking standard sized sheets, (8½ x 11 in.) which contain the name-plate data and other specifications desired of all plant equipment. It will of necessity need to be indexed and in order to properly classify the equipment and indicate just what is covered under each heading, a second index to the first is desirable.

This first index (Index A) classifies the equipment into certain headings assigning to each a certain number as shown in the illustration. As will be noticed the numbers are taken sufficiently far apart so as to permit of future expansion.

The second index (Index B) subdivides each heading and states just what equipment is included under this heading. For instance, under "boilers" are included the drums, tubes, etc., but not breeching, draft fans or stack. These are listed under "fan units" and must be considered under this

heading. It can be readily seen that unless some such arrangement is adopted much confusion would result due to the fact that much of the equip-

Fig. 1—Record Book

ment, on account of its being connected together or on account of its very nature, would tend to overlap on the records. The inventory proper follows this second index and since each main heading is begun on a separate sheet, additional data on new equipment can always be inserted without inconvenience.

The Equipment Tickler File

The *equipment tickler file* consists of a small card file with numeral index from 1 to 30 inclusive. White and yellow cards with the printed form shown in Fig. 4, are inserted in the file.

The white cards carry the numbers of plant equipment as outlined in Index "B". The yellow cards carry any job number for any particular piece of equipment.

The purpose of this file is to enable the engineer in charge to check the records of a designated few pieces of equipment, each day, as shown by the tickler cards for that day. If the card is white it means that a complete piece of equipment as listed under Index "B" is to be checked. If the card is yellow it means that only a certain job or operation on a piece of equipment is to be checked.

The white cards are arranged so that one or more of these cards, depending upon the amount of equipment, will come up each day for the thirty days indicated by the numerals of the index. In this manner every white card will appear every thirty days unless certain days of the month are omitted, such as Sundays, in which case the interval will be approximately every thirty days.

The yellow cards are, as stated above, for a particular job only, and are inserted in the tickler file to come up after the interval desired. For instance, if a certain motor bearing gave trouble and in the engineer's opinion this bearing should be drained of oil each week until no further trouble is experienced, he would use one of the yellow cards and enter "one week" or "seven days" in the place provided and place it seven days ahead in the file. If the desired interval is for longer than thirty days it is treated in a similar manner except that each time it is encountered in the file, (every thirty days) it is disregarded until the proper date has been reached, as indicated by the interval from the last entry made on the card.

The Memorandum Form

The *memorandum form,* shown in Fig. 4, is used throughout the plant by both employees and the chief engineer. When used by an employee it is for the purpose of reporting a job done on a certain piece of equipment, a notice that a certain trap was found leaking, or for reporting the need of certain material, tools, etc. When used by the chief engineer it usually becomes an order. These memorandums are printed in pad form and arranged for making a duplicate copy and each employee or group of employees will keep one pad available for their needs. Suitable deposit boxes for these memorandum slips should be placed at some convenient point.

Operation of The System

In carrying out this system, the employee, making the notation on the memorandum form, drops it in the "outgoing" compartment of the box. Once daily, preferably each morning, all memorandum slips are gathered from the boxes and placed on the

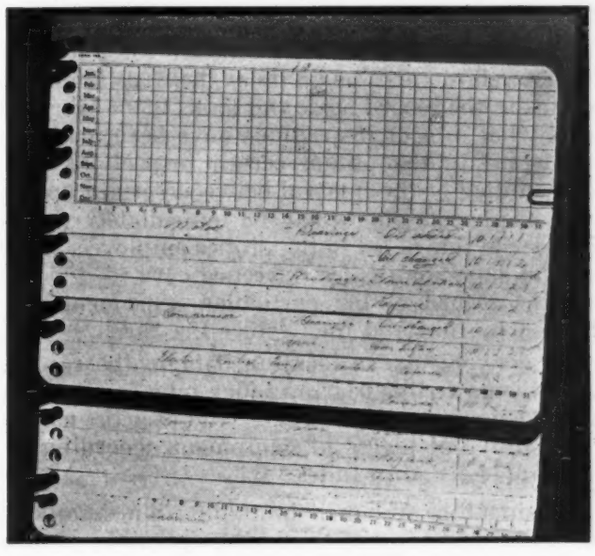

Fig. 2—Record Form.

Chief Engineer's desk. Upon receiving these slips, the information relating to plant equipment as to repairs, oil changes, inspections, etc., is entered in the record book. Memorandums requiring action by the Chief Engineer should receive his notation concerning the subject reported and together with other orders or notices that he may choose to give that day, be distributed to the boxes, being placed

EAST PLANT
Equipment Inventory
INDEX "A"

NAME	NUMBER
Battery Equipment	1
Boiler Units	5
Compressor Units, Air	10
Condenser Units	15
Coolers, Air	19
Coolers, Oil	20
Crane	25
Deaerators	30
Exciter Units, Steam and Motor Driven	31
Exciters, Shaft (See Turbine Units No. 95)	
Elec.Equip.-Indoor (13200 V Bus Structure)	40
Elec.Equip.-Indoor (Main Switchboard)	41
Elec.Equip.-Indoor (440 V [illegible])	42
Elec. Equip-Indoor (Miscellaneous)	43
Elec.Equip.- Outdoor (44000 V Equipment)	45

EAST PLANT
Equipment Inventory
INDEX "B"

NAME

No. 1. BATTERY EQUIPMENT

1.1 Battery Equipment: Batteries, Motor Generator Electric Control Equipment.

No. 5. BOILER UNITS

5.1 Boiler Unit #1: Drums, Tubes, Brickwork, Baffles, Superheater (drums & tubes) Copes Regulator, Safety Valves, Blowdown valves, Water Column, Burners, (oil & gas) Damper, Automatic Valve, Piping, Valves, etc.

5.2 Boiler Unit #2: Same as Unit #1.

5.3 Boiler Unit #3: Same as Unit #1, except add Hagan Regulators.

5.4 Boiler Unit #4: Same as Unit #1.

5.5 Boiler Unit #5: Same as Unit #1.

No. 10. COMPRESSOR UNITS, AIR

10.1 Compressor, Air (Motor Driven) Motor, Compressor, Electric Control Equipment, Tank, Piping, Valves, etc.

No. 15.1

CONDENSER UNIT - NUMBER ONE:

Condenser: One Westinghouse surface condenser. size - 9500 square feet, Serial No. 2674, Westinghouse Electric & Manufacturing Co, South Philadelphia, Pa.

Atmospheric Relief Valve: One #21102 Atmospheric relief valve, 18 multiflex - C.H. Wheeler Manufacturing Company, Philadelphia, Pa.

No. 15.2

CONDENSER UNIT - NUMBER TWO:

Condenser: One Westinghouse surface condenser. size - 8800 square feet, Serial No. 2719, Westinghouse Electric & Manufacturing Co, South Philadelphia, Pa.

Atmospheric Relief Valve: One No. 21818 - 18 multiflex Atmospheric Relief Valve, C. H. Wheeler Manufacturing Company, Philadelphia, Pa.

No. 15.3

CONDENSER UNIT - NUMBER THREE:

Condenser: One Westinghouse surface condenser. size 16,500 square feet, Serial No. 2919, Westinghouse Electric & Manufacturing Company, Philadelphia, Pa.

Atmospheric Relief Valve: One Crane Atmospheric Relief Valve. Crane Company.

Fig. 3—Inventory Pages.

in the "incoming" compartment. By this means the record is kept posted from day to day and all information is up-to-date.

In posting this information in the record, the reporting employee's initials are placed in the proper square opposite the particular month and date. Any other notations may, of course be made if desirable. This part of the work may well be assigned to the engineer's assistant.

The next step is the use of the tickler file. In using this, the engineer withdraws the cards, (white, yellow or both) from the file for the particular date and by using the equipment number (or job number if a yellow card) as an index, he finds the proper slips in the record book and looks them over and notes what jobs or inspections have been made up to date. If, in his opinion, certain inspections have been omitted or the interval between certain operations has become too great, he immediately writes an order to this effect to the proper employee. After this, he dates the tickler reference card to indicate that the record of the particular equipment was checked by him and then refiles the card.

For convenience in locating data in the record, special yellow slips bearing index tabs are inserted at the various headings (Fig. 2) and bear the names of the different pieces of equipment according to the manner listed in Index "B."

In using this system it is of the utmost importance that anything affecting the operation of any machine be reported. If this is not done, the record will be of little value. It has been found that at the end of each day, a few minutes set aside for this purpose will insure success of the system. Operations or orders of an emergency nature cannot, of course, be delayed but such items should be properly recorded after the job is completed. Likewise, any verbal orders that may be given by the Chief Engineer, if they concern the repairs or operation of a machine in the plant, should be accounted for by the employee concerned in a written memorandum.

In stating that a memorandum report should be given by an employee upon finding a condition that requires attention, it is assumed that the necessary repairs, etc., required are not a part of his regular duties, or of such a nature as to require approval from the Chief Engineer before going ahead.

The following advantages are obtained by such an equipment record system: better resultant performance of equipment; accurate knowledge of the conditions of any specific machine; placing of responsibility for the performance of each operation on the proper employee thus eliminating the possibility of damage to the equipment through unskilled hands; permitting of no job to be overlooked

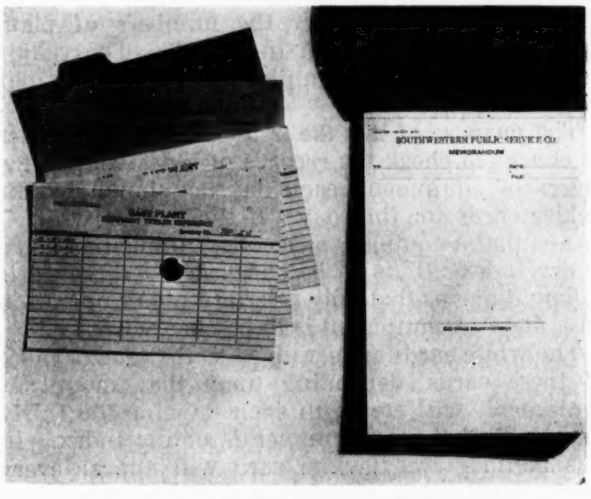

Fig. 4—Memorandum Form.

or forgotten; eliminating unnecessary labor in that certain definite operations are outlined by the engineer in charge, instead of being left up to the em-

(Continued on page 40)

Dual Purpose Power Plants for Commercial Distribution of High Pressure Steam*

By JOHN M. DRABELLE Mechanical and Electrical Engineer
Iowa Railway and Light Corporation
Cedar Rapids, Iowa

The author discusses the present situation of public utilities with respect to technical developments of recent years which have contributed to more economical and efficient production of steam-electric power and then points out the opportunities of extending utility service to industrial plants, buildings, etc., by means of dual-service plants supplying both steam and electric service. This discussion is given a highly practical and informative value by the inclusion of descriptive matter and other data pertaining to a number of plants now operating along these lines.

THERE are certain salient facts concerning dual purpose power plants which must be borne in mind in any consideration of the subject. They may be summarized as follows:

1. Each case must be worked out for itself.
2. The system proposed is not applicable to low pressure, low temperature power stations small in size.
3. It is not applicable to small units—the dividing line seems to be somewhere between one thousand and two thousand kilowatts of capacity and up.
4. Stations of the dual-purpose type built near business districts should also serve as electric distributing centers reducing the size and capacity of feeders into the business territory and resulting in a saving in electrical layout.
5. The dual-purpose heating station becomes a relay or an emergency station for extra high class service, such as in business districts.
6. The dual-purpose station is a factor in the smoke problem of a city due to the reduction in smoke, as it is obvious that one large central station with a well operated boiler plant will contribute less pollution to the atmosphere than a multitude of small plants with indifferently operated boiler plants.
7. That the economic failure of the small isolated dual-purpose station is due first to inadequate equipment and lack of diversity of load both electric and steam, and the success of the large dual-purpose station with its steam distribution net work is due mainly to the larger units and a better diversity of load both steam and electric.

Few people, even those in the industry, fully realize or appreciate the vast progress that has been made in the last twenty years in the science and art of generating electric power by steam. In recent years, this progress has been accelerated by such factors as improvements in boiler furnace design and methods of fuel burning, the use of substantially higher steam pressures and temperatures and the use of the regenerative steam cycle. The use of binary cycles such as are represented by the recently developed mercury-vapor turbine holds the promise of still further progress.

Those that think in terms of hydro-electric power as being a low-cost source of energy realize that hydro-electric units have practically reached their ultimate in efficiency and the only progress being made today is in higher speeds resulting in lower cost of water wheels and generators, but as these comprise but about twenty per cent of the cost of a hydro-electric installation such reductions have comparatively little effect on the overall cost of the job. In contradiction to this, in the steam power plant due to higher pressures and temperatures and the use of alloy steel, smaller piping is being used. Turbines develop a greater capacity per pound of material with the tendency of the cost of steam generating equipment to become lower rather than higher.

The accompanying charts give a picture of what is being accomplished in the range of high temperature. Fig. 1 shows in the solid curve the station heat rate Rankine Cycle, no regenerative feed

* Presented before the Mid-west Division of the National Electric Light Association meeting at Excelsior Springs, Missouri, May 20-22, 1931.

water heating, with steam at a temperature of 700 deg. fahr. for various pressures ranging from 200 to 2000 lb. The broken curve shows the per cent saving over the 200-lb. plant. These curves are plotted between steam pressure and thousands of B.t.u. per net kilowatt hour.

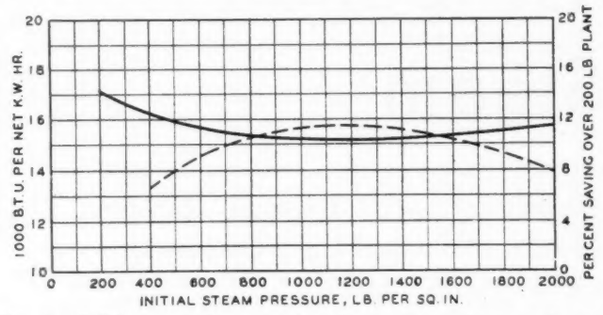

Fig. 1—Solid curve shows station heat rate rankine cycle, no regenerative feed heating, steam at 700 deg. fahr. Broken curve shows per cent saving over 200-lb. plant.

Fig. 2 shows the heat rate with four stages of regenerative feedwater heating, with steam at a temperature of 700 deg. fahr.; the broken curve showing the present saving over a 200-lb. plant. These curves are plotted with steam pressure ranging from 200 to 2000 lb. and thousands of B.t.u. per net kilowatt hours and show the saving over the 200-lb. plant. Figs. 1 and 2 give a very definite picture of what high pressure and regenerative feedwater heating accomplish in the high pressure station.

Fig. 3 shows the station heat rates for various initial steam pressures and temperatures assuming five pounds per square inch gage back pressure, feedwater heated to 212 deg., for a large turbine plant using 20,000 kw. units. This family of curves is plotted for various pressures ranging from 200 to 2000 lb. with initial steam temperatures of from 700 to 1000 deg. fahr. and the result

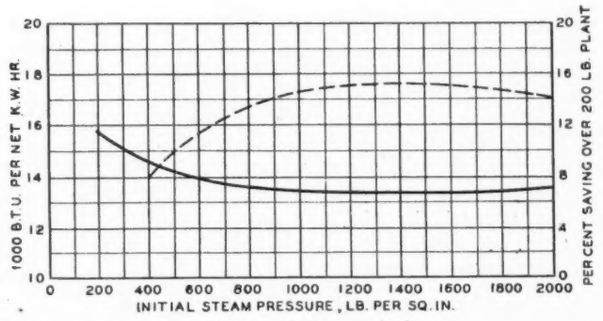

Fig. 2—Solid curve shows heat rate with four stages of regenerative feed heating and steam at 700 deg. fahr. Broken curve shows per cent saving over 200-lb. plant.

expressed as thousands of B.t.u. net per kilowatt hour.

Fig. 4 shows station heat rates for various initial steam pressures and temperatures, assuming five pounds per square inch gage back pressure, feedwater heated to 212 deg., with a small turbine plant of 2000 kw. units. This family of curves is plotted between 200 and 2000 lb. gage and from 700 to 1000 deg. fahr. with the result expressed in thousands of B.t.u. per net kilowatt hour. This indicates very clearly the effect of high temperatures upon station economy and the difference between large and small units showing that much progress has been made in the design and increased efficiency of the smaller units.

Fig. 5 gives the net power made available from a given weight of steam at various initial conditions, with five pounds per square inch back pressure, with the feedwater heated to 212 deg., and large units of 20,000 kw. This family of curves is plotted between 200 and 2000 lb. gage, the temperatures ranging from 700 to 1000 deg. fahr. with the result expressed in net kilowatt hours per 1000 lb. of steam supplied to the turbine unit. Within the range of metals available today, this shows an increase, in the 600-lb. territory with 700 deg., of 60 kw. hours per 1000 lb. to 74 kw-hr. per 1000 lb. when the steam temperature is 900 deg. with the pressure remaining at 600 lb.

Fig. 6 gives the net power made available from a given weight of steam at various initial condi-

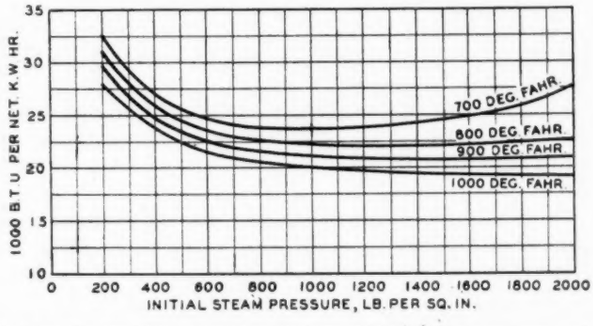

Fig. 3—Station heat rates for various initial steam pressures and temperatures, 5 lb. per sq. in. back pressure, feedwater heated to 212 deg. fahr. Large turbine plant (20,000-kw. units).

tions, with five pounds per square inch back pressure, feedwater heated to 212 deg., and small units of 2000 kw. This family of curves shows the net kilowatt hours per 1000 lb. of steam supplied to the turbine with pressures varying from 200 to 2000 lb. gage and temperatures from 700 to 1000 deg.

Another possibility in connection with central stations, operating in conjunction with or as part of an industrial or manufacturing plant, is the use of so-called industrial wastes as will be mentioned later on. One station employs refinery wastes that are impossible to sell to the trade and yet carry considerable heat value. Another possibility, particularly in connection with pulverized coal installations, is the use of off-peak gas from pipe lines. Modern pulverized coal furnaces, when equipped with the proper burners are equally adaptable to the use of gas fuel, and the matter of load factor to pipe line companies is a serious one as well as to the company purchasing gas—a higher load factor makes for lower rates.

The purpose in presenting these curves is to show clearly just what is being accomplished in the art of steam generation and the thermodynamic prog-

ress that has been made in a relatively few years in obtaining more kilowatt hours per ton of coal.

While in theory at least, the utility business is non-competitive, in its endeavor to secure large industrial power loads it is highly competitive in character.

Public utility power stations have their location fixed generally by transportation facilities for fuel, and an adequate supply of condensing water. This usually fixes their location, in the so-called industrial districts of cities and towns, and with a little further study such a location could be tied up with the possibility of supplying to adjacent manufacturers a complete service, namely, electric power and steam for heating and process purposes. In this manner a higher load factor can be secured for the boiler plant, and for the power generation equipment, with certain modifications such as bleeder and back pressure turbines to handle this load.

When industrial plants were small, it was difficult for such plants to secure adequate financing for the development of their power supply and

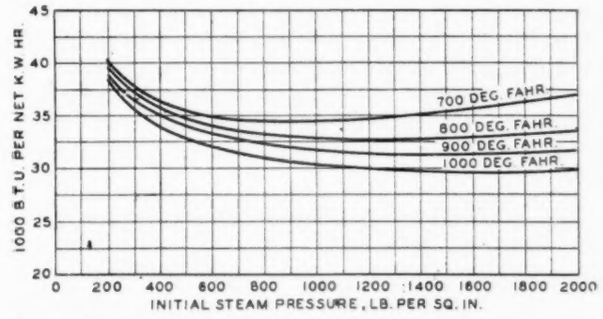

Fig. 4—Station heat rates for various initial steam pressures and temperatures, 5 lb. per sq. in. back pressure, feedwater heated to 212 deg. fahr. Small turbine plant (2000-kw. units).

competent engineering help for the design, construction, maintenance, and operation of such undertakings. The technical schools of this country have furnished a large percentage of their graduates in the past to the central station industry, but due to the extensive consolidation of public utilities that has taken place in the last few years, the present supply of such technical graduates has been greatly in excess of the utility demand. In fact, the utilities have released a large number of experienced, competent, well trained men, thoroughly versed in large power station operation, who can build and operate successfully large power stations for industrial plants.

Today the larger industrial plants not only have an adequate supply of competent personnel but are also disposed to take full advantage of the developments which characterize modern practice in steam generation. They now have at their command pressures ranging from 450 to 1200 lb. gage with accompanying high superheat and with a consequent high kilowatt hour recovery from steam turbines of the "reducing valve" type. This is the situation in the large power field today.

To the smaller manufacturer there is offered a multiplicity of prime movers ranging from small back pressure turbines to oil engines. For the hotel, the office building, and similar situations there are offered various combinations of moderate high pressure boilers (250 lb.) with heat bal-

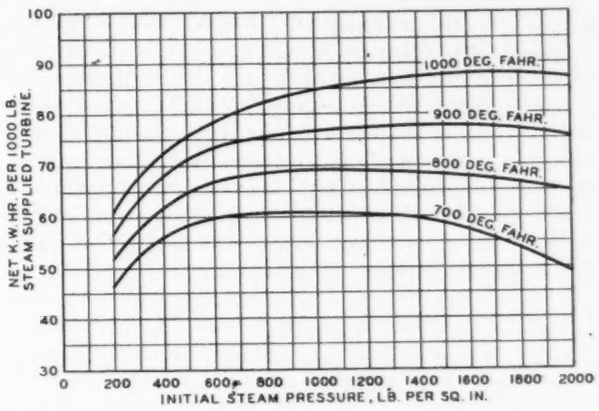

Fig. 5—Net power made available from a given weight of steam at various initial conditions, 5 lb. per sq. in. back pressure, feedwater heated to 212 deg. fahr. Large turbine plant (20,000-kw. units).

ance schemes combining various types of reciprocating steam engines, steam turbines, and a recent combination of oil engines.

This is in a few words the situation that the public utilities find themselves in today, and the question is, what are they going to do about it? The day of the public utility in the larger cities and towns offering but a single service, namely, electric light and power, to industries, office buildings, hotels, and similar situations, is rapidly becoming past history due to the demand of customers for a "complete service."

The utility must therefore, in order to retain its electric light and power business and to secure additional business be prepared to offer and deliver

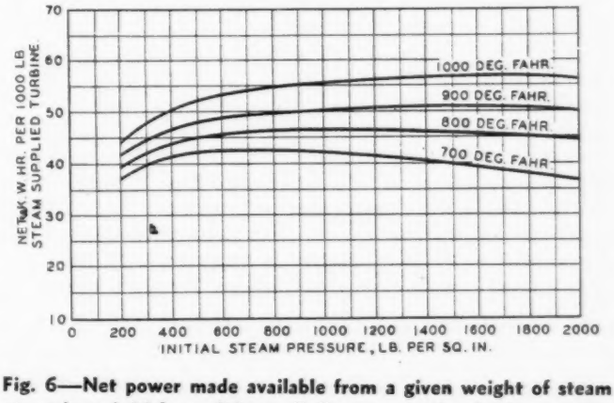

Fig. 6—Net power made available from a given weight of steam at various initial conditions, 5 lb. per sq. in. back pressure, feedwater heated to 212 deg. fahr. Small turbine plant (2000-kw. units).

a complete service, to meet the various demands of different users. For example, for the hotel and office building it must be ready to supply three commodities, steam for heating purposes, electric light and power. This service must be furnished at a rate which is stripped of everything except

cost plus a profit. For the small manufacturer, the requirements are practically the same as those of the hotel and office building. As the electric motor of the nineties gave to small industrial plants ample power at a cost comparable with that of plants which were large enough to manufacture at the then accepted costs, so today will this dual service to industrial plants make possible the creation of industries of small size, which to date have been unable to compete on account of cost of service made expensive because of the lack of balance between the use of power and steam. For the larger manufacturer, the utility must be prepared to furnish not only large quantities of electrical power, but also steam at varying pressures, and temperatures, according to the peculiar demands of that particular manufacturer. And for a fourth group, represented by the very large manufacturing plant using large quantities of process steam, the demand for which does not coincide with the demands for electric power, the service offered by the utility must be along the lines of parallel operation with such a plant for heat balance purposes. Stated briefly, this is accomplished as follows: when the manufacturing plants' electric demand is low, but with process steam demand high, then by loading up the prime movers in the manufacturing plant electric energy can be delivered into the lines of the utility company. When the reversed condition is true, with electric demand high but with process steam demand low, then the lines of the utility company can deliver to the manufacturer the necessary additional increment of electric power required, represented by the difference between the total demand for electric power and the electric output of the manufacturer's prime movers which are then supplying only the required demands of process steam. Such a scheme of heat balance operation means that at times of high electric demand and low process demand, steam is not wasted over the roof.

Several recent power station developments, widely scattered geographically, have been built in this country to meet the various problems previously stated. Among these is the Deep Water station of the Deep Water Light and Power Company, which is a combination power plant of the United Gas Improvement Company and the Atlantic City Electric Company, combined with an electrical and steam supply service to E. I. DuPont De Nemours and Company. The DuPont equipment in this station is of particular interest in connection with this discussion. A single cylinder non-bleeding, non-condensing turbine rated at 12,500 kw., 8 power factor has been installed. This unit operates at 1200 lb. pressure and 725 deg. fahr. total steam temperature and exhausts at 200 to 400 lb. into seven evaporating units of 4430 sq. ft. each. These evaporators, when receiving 530,000 pounds per hour of exhaust steam from the 1200 pound turbine, will generate 400,000 lb. of vapor per hour at 180 lb. gage pressure and superheating the vapor to 440 deg. fahr., total temperature. This is a typical case of combination supply and a complete service to the large power consumer.

Another installation, is that of the Southeastern Production Company at Mobile, Alabama, a power plant designed and built to furnish both power and steam to a new paper mill of the International Paper Company. This station will supply a total steam requirement of 135,000 lb. per hr. divided as follows:

85,000 lb. per hour at 150 lb. pressure and 100 deg. superheat, and 50,000 lb. at approximately 35 lb. pressure, and 2 per cent moisture. The Production Company, under its contract, agreed to install electric generating facilities having a rated capacity of 7500 kw. to furnish power to the mill. The Production Company station is tied in with the lines of the Alabama Power Company for interchange of facilities and for the maintenance of heat balance. The Production Company has the right to deliver any or all of the electrical energy from or to the Alabama Power System.

The make-up water requirements will run under the above conditions as high as 60 per cent. Relatively low boiler ratings were decided upon by the Production Company's engineer. Three 1311 hp. bent tube boilers, fired by underfeed stokers were installed. The operating conditions are,—475 lb. steam pressure and 650 deg. total steam temperature.

The prime movers include one 2000 kw. condensing unit and one 6000 kw. back-pressure, double extraction type, eight stage turbine, equipped with two arm mechanism for back pressure and extraction control. Extraction openings are provided in the latter turbine shell after the first and sixth stage at which the steam pressure is held practically constant at the pressures of 150 lb. and 35 lb. respectively. The maximum rate of steam extraction at the 150 lb. point is 100,000 lb. per hr. and at the 35 lb. point, 70,000 lb. per hr. The exhaust section of the turbine is designed to pass 20,000 lb. per hr. The exhaust pressure is regulated automatically to any value between 0 and 5 lb. gage.

A third installation is that of the Louisiana station of the Louisiana Steam Products Incorporated near Baton Rouge, Louisiana. This station has been constructed adjacent to the refinery of the Standard Oil Company of Louisiana, and will supply to the Oil Company approximately 840,000 lb. of steam per hr. at 135 lb. pressure and 438 deg. total temperature, and electrical power up to approximately 16,000 kw. maximum to the refinery. Steam will be generated at 640 lb. gage, and 750 deg. total temperature, and will pass through two or more of three 15,000 kw. steam turbines which will exhaust at the pressure and temperature of delivery to the refinery. Electric power generated in excess of that required by the refinery will be supplied to the Baton Rouge Electric Company, or to the transmission system of the Gulf States Utilities Company.

The exceptionally high load factor of this plant (about 80 per cent estimated) justifies certain refinements, such as the use of both economizers and air preheaters in the boiler units. On the other hand, the fact that this is primarily an industrial plant has not warranted the expenditure for building structure that is usually considered desirable for a public service plant of this size, and efforts are being made to obtain extreme simplicity in building and equipment, without sacrificing economy or electric generating capacity.

The main turbines will be simple, high-pressure, non-condensing machines. Low pressure steam for three-stage, feedwater heating will be obtained from the various steam-turbine-driven auxiliaries; the boiler feed-pump turbines are to exhaust at about 5 lb. absolute to the low pressure heater, and the fan turbines are to exhaust at about 5 lb. gage to the deaerators. Steam for all auxiliaries and the high pressure water is to be taken directly from the main turbine exhaust lines. All other plant auxiliaries, except one fuel oil pump, will be motor-driven.

An unusually complete water purifying plant, which will consist mainly of settling, clarifying, filtering, treating and softening equipment, with a capacity of 2000 gal. per min. of treated Mississippi River water, is being provided to supply the large amount of boiler feed make-up required.

The boiler plant is unique in that the fuel will be approximately 50 per cent natural gas, 33 per cent liquid refinery waste, and 17 per cent petroleum coke. The petroleum coke will be burned in pulverized form.

Another interesting combination station is that of the Western Electric Company at Point Breeze, Maryland, operating in combination with the Consolidated Gas Electric Light and Power Company of Baltimore, Maryland. This station does not generate any electrical power owing to the extremely varying steam demands, but is operated by the utility company under a five-year contract, for the Western Electric Company, the utility company undertaking to furnish steam and electrical energy without at the present time any production of by-product power.

Particulars	Initial	Ultimate
Power for Process Demand	13,000 kw.	28,000 kw.
Power House Auxiliary and Lighting	1,300 kw.	3,300 kw.
Process Steam—100 lb. pressure	44,000 lb./hr.	71,000 lb./hr.
Process Steam—200 lb. pressure	11,000 lb./hr.	21,000 lb./hr.
Heating (15 lb.) Annual Consumption	123,000 M lb.	400,000 M lb.

These are typical cases of large undertakings involving large requirements of both steam and electricity, the economics of which demand heat balance.

To meet the conditions typical of the business district of a large city, the solution of the Rochester Gas and Electric Corporation of Rochester, New York, a part of the Associated Gas and Electric System, is of interest. This company has gone into steam heating in the business district of Rochester quite heavily. It has constructed adjacent to the business district a modern high pressure, high temperature generating station, employing pulverized coal for the firing of the boilers with steam turbines extracting steam at approximately 125 lb. pressure for the high pressure system, and for the low pressure heating system expansion through the turbine to 15 lb. gage.

To meet the requirements in the manufacturing district of Rochester two stations have been constructed supplying both steam and electrical power. The system in Rochester involves a total of 11,750 kw. of installed capacity of non-condensing turbines, some straight non-condensing, and some of the non-condensing bleeder type. Approximately 10,000 kw. of capacity is delivered by these dual-purpose stations during the months of November, December, January and half of February, which is approximately thirteen per cent of the total system load, and these by-product power plants reduce the capacity required in the company's main condensing steam station by that amount.

An example of what has been accomplished at Rochester in the combined electric and steam service to industrial plants is shown in Table 1, giving the power generation, steam demands and service bills for this station:

TABLE 1

	1928	1929
Low pressure steam (M lb.)	65,441.7	70,566.7
High pressure steam (M lb.)	79,643.1	80,299.5
Total Steam (M lb.)	145,084.8	150,866.2
	Kw.	Kw.
d.c. peak demand	400	400
a.c. peak demand	1,304	1,304
Kw-hr., d.c.	809,600	903,900
Kw-hr., a.c.	3,147,600	3,484,800
Total Steam Bill	$ 74,560.17	$ 75,382.78
Total Electric Bill	$ 68,445.71	$ 75,672.32
Combined Total Bill	$ 143,005.88	$ 151,955.10

A further growth into the industrial business combining electric power and steam is shown in Table 2 which gives details as to steam and electric revenue for this station:

TABLE 2

	1928	1929
Steam Income	$ 72,616.89	$ 74,368.39
Electric Income	82,715.47	115,913.52
Combined Total	$155,332.36	$190,281.91

These figures are for the purpose of showing what can be accomplished if proper equipment is available and a proper and unprejudiced analysis made.

Since 1914, the Iowa Railway and Light Corporation has furnished all of the steam and electric power to the mill of the Quaker Oats Company of Cedar Rapids, Iowa. This load has grown from approximately a maximum steam load of 20,000 lb. per hr. and 1400 kw. in 1914 to a present maximum steam demand of approximately 70,000 lb. per hr. and a maximum electric demand of approximately 7500 kw. The Iowa Railway and Light Corporation has also been engaged for many

years in the central heating business in Cedar Rapids, supplying both high and low pressure steam service to hotels, office buildings, and hospitals. The following approximate quantities are of interest:

TABLE 3

Service	Pounds per hour
Low pressure heating system	90,000
High pressure heating system	30,000
Steam to Quaker Oats Company	70,000

This gives an approximate total maximum demand of 190,000 lb. of steam per hr., with a simultaneous coincident demand of 170,000 lb. per hr.

The approximate annual steam consumption is as follows:

TABLE 4

Low pressure heating system	180,000,000 lb.
High pressure heating system	65,000,000 lb.
Quaker Oats Company steam	170,000,000 lb.

The heating system, when originally installed at Cedar Rapids, had as its source of supply the exhaust from non-condensing steam engines. As the development in the central station art progressed this station was gradually rebuilt and equipped with condensing steam turbines, the engines were replaced with turbines and the central heating system supplied more and more of its load in the form of live steam through a reducing valve, until it was entirely on a live steam basis.

In order to secure energy recovery from this steam at 225 lb. gage and 100 deg. superheat, a by-product turbine of the reducing-valve type has been installed and recently placed in service. This is a 7500 kw. non-condensing turbine taking its steam from the main head of the station at 225 lb. gage and 100 deg. of superheat. The turbine, by means of a stage valve, extracts steam at 100 lb. gage from the first stage, for the heating of feedwater and for high pressure steam service. Steam passes through the other four stages of the turbine to the low pressure heating system at varying pressures of from 5 to 25 lb. gage, depending on the steam demands and pressure requirements of the city. The turbine is capable of passing a maximum throttle flow of 250,000 lb. of steam per hr., with steam extraction up to 90,000 lb. per hr. of the first stage, and a flow to the low-pressure heating system of 160,000 lb. per hr. It is expected that this turbine will deliver to the station bus approximately 12,000,000 kw-hr. per yr. and add a potential capacity under winter conditions of 7500 kw.

In considering such equipment for by-product power purposes it must be borne in mind that such a unit requires no other equipment than the unit itself, no condenser, no circulating water and other associated auxiliaries that go with a condensing turbine. Such an installation has been actually made for about twenty-five to forty dollars per kilowatt. The B.t.u. rate of the machine is approximately less than 4,000 B.t.u. per kw-hr., considering only energy recovered, and the steam passed through the machine is available for central station heating service and feedwater heating.

The turbine is equipped with a special governor mechanism so as to maintain constant first stage extraction pressure, and constant pressure at the exhaust to the low-pressure heating system. The pressure at the exhaust is adjustable. The governor of the machine will automatically load up the turbine to meet the requirements of the high-pressure flow and secondly the low-pressure exhaust flow.

Public utility management should not overlook, and should give due consideration and due credit to the combined steam and electric plant with dual service. The availability of such a service forms a large factor in the economic set-up of an industrial plant, and if omitted by the utility in its analysis, imposes a very severe penalty upon the utilities economic set-up. There is a tendency on the part of many utility companies to ignore the capacity factor of this by-product power equipment, merely because it is not large enough to displace a 50,000 kw. or larger capacity turbine. These bleeder non-condensing turbines operating from 225 lb. and 425 lb. gage, with commercial superheats available today, will generate a kilowatt hour at approximately 4000 B.t.u. per kw-hr. and have by-product steam available for other purposes which will permit the utilities to be competitive in the industrial power field, to meet the competition of the isolated plant and the oil engine salesman, and to supply to the small users a complete service thereby eliminating the isolated plant of any type or combination.

The author of this paper makes due and grateful acknowledgement for information furnished by Mr. Bouscaren of Stone and Webster, Inc.; Mr. M. J. Niessen, vice-president of the Southeastern Production Company; Mr. Roger DeWolf, assistant superintendent of the Utilities Management tant superintendent, Utilities Management Corporation; Mr. F. C. Chambers, general manager of the Iowa Railway and Light Corporation, and Dr. C. F. Hirschfeld, The Detroit Edison Company.

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An Equipment Record for the Plant

(Continued from page 34)

ployees themselves; and the opportunity of studying costs from both labor and material standpoints for each piece of equipment in the plant.

It is evident that the Chief Engineer is responsible for seeing that a regular inspection schedule is followed since he alone issues orders to this effect except where certain minor inspections fall in an employee's regular line of duty. It is up to him to see that special jobs or inspections are listed on the yellow cards of the tickler file, the white cards, on the other hand, prompting him to check over the record of particular pieces of equipment at the regular interval of thirty days.

Memorandum slips, after being posted in the record may, of course, be filed away according to months for future detailed reference if desired.

Balancing Supply and Consumption of Energy

A Discussion of Power Plant Practice and Trends in Great Britain and Europe

By C. H. S. TUPHOLME, London

The author discusses the factors involved in balancing the generation and consumption of energy as well as those contributing to greater economy in the production of steam and the generation of electricity. As the title indicates, his consideration of the subject is limited to European practice. Consequently many American engineers will find little that is novel in the trends and developments discussed. They will, however, find the article interesting as indicating present conditions and the direction of developments in European practice.

IN recent years much attention has been paid to obtaining a suitable balance between the supply and consumption of energy, a practice which in many countries has received great impetus because of conditions which necessitated the greatest possible economy both in operating costs and the expenditure of capital. In establishing this balance and thus securing a reduction of operating expenses by means of a better utilization of the sources of energy and more efficient generation, transmission and utilization of energy, it has been necessary to provide a certain flexibility in the whole system in case of unexpected failure of supply due to a breakdown or any sudden demands for an unusual quantity of energy for emergency service, etc.

The correct solution lies in the proper location and centralization of the generating plant which can only be accomplished when considered in conjunction with the nature of the supply and demand. It also depends closely on the factors of distribution of the sources of energy, the possibility of transporting or transmitting the energy, and the possibility of storing energy or utilizing any surplus energy.

The chief advantage of centralization lies in the adoption of larger units for central stations, transformers and distributing apparatus, designed to suit the plant at its final stage of development. Generally, therefore, the preliminary scheme must be based on assumptions concerning the amount of electricity which will ultimately be required and consequently on the probable industrial developments during the next few years or decades. Such assumptions may eventually prove to be absolutely wrong, in consequence of unforeseen circumstances, so that the question of utilizing the then surplus energy will arise, perhaps compelling the generating station operators to work in collaboration with manufacturers or even to start manufacturing themselves, as has been done in Japan.

In addition, a system of high-tension transmission lines necessitates a large capital outlay; therefore the number of hours worked at full load per annum must be high, otherwise the cost of transmission per kw-hr. will be prohibitive. Hence such lines can be considered only as suitable for transmitting the energy generated in the base stations which employ water power or local fuel such as lignite. Peak loads are more economically taken by plants installed in the immediate neighborhood of the centers of consumption.

In spite of the constantly increasing electrification and of the centralized generation of energy, it has been found in many industries that an economical solution of the problem of balancing the supply and the consumption of energy is to be found in another direction. In the majority of cases met with in practice—and these are exactly the ones most interesting for the engineer who prepares the schemes, and the manufacturer who takes part in them—the problem is to extend or to combine existing systems of plant which from the present-day point of view are more or less antiquated or uneconomical. The engineer preparing such schemes has now to work within much narrower limits than heretofore because of the question of expense. This is a primary factor, particularly in private works, and especially when a plant develops rapidly and consequently has only limited means of its own to pay for extension and renewals.

Owing to recent developments in the use of high

steam pressures and in the utilization of surplus energy, it is now possible to generate energy more economically by adopting high-pressure two-stage plants for steam power stations and combining the generation of steam for power and heating or process purposes in an economical manner for industrial undertakings and district central heating plants, as used for large towns.

Even if decentralization cannot be recommended in principle, partial decentralization or even independent generation of energy should nevertheless be adopted wherever economical advantages can at the same time be obtained. This eliminates consumers who prevent a reliable judgement being formed as to the probable development of the demand for power in the years to come. Centralization of the generation and distribution of energy can then be limited to the groups of consumers who are seen to be constantly developing their works and in whose case the increase in the demand for energy in future years can therefore be estimated fairly accurately, as for example, in electric railway systems, lighting of large towns, etc., while under

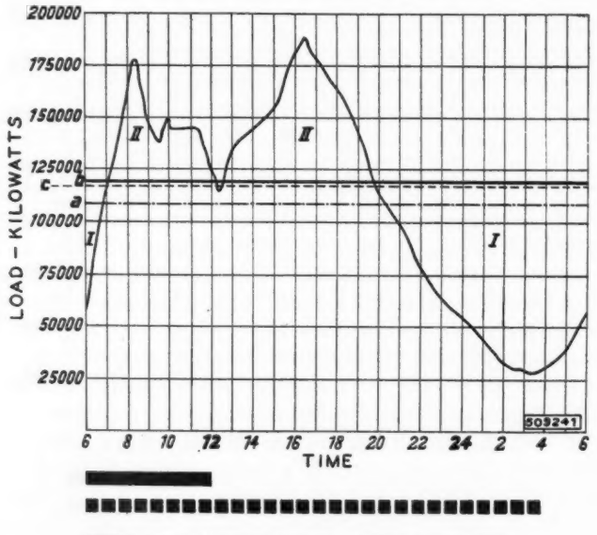


Fig. 1—Plant load chart showing effect of daily energy storage.

certain circumstances provision may also be made to allow for any increase in the general industrial demand.

In this manner it is possible to obtain fairly regular and economical utilization of the output from large central generating stations, possibly combined with a hydro-electric storage plant with overhead transmission lines and transformer plant.

One example of the use of a daily hydro-energy storage plant can be seen from the load diagram taken during a day in winter in an electricity works in the Ruhr industrial district, Fig. 1. The line (a) shows the mean load on the power station without storage; the line (b) is the mean load with daily storage; and the line (c) is the load with daily and weekly storage. From this diagram it can be seen that the load on the power works fluctuates between 30,000 and 189,000 kw. in the course of 24 hr. The line of mean load (a), however, lies at about only 109,000 kw., the line (b), when balancing the daily load with the help of a storage plant, lies at about 119,000 kw. With combined daily and weekly balance, if the total output is distributed over the whole 7 days, the mean daily load line (c) lies at about only 117,000 kw. in consequence of the greatly reduced consumption on Saturdays and Sundays.

The primary principle of energy storage is the conversion of kilowatt-hours which cost little to generate, into kilowatt-hours which can be sold at high rates, as is shown by the comparison between generating costs and receipts in Fig. 1. Uniform utilization of the base power station is only a secondary consideration.

For the most economical operation it is essential that the steam plant should be able to burn a variety of coals ranging down to the low-grade cheaper sorts.

Considerable improvements in overall efficiency have been effected in recent years by the introduction of higher working pressures, intermediate superheating, feedwater preheating, the use of extracted steam and the installation of air heaters. It should be noted that the most economical conditions of steam service cannot in general be determined at once, since they depend not only on the price of coal but also on the loading of the plant, size, etc. A decisive factor is, of course, the increase in initial cost entailed by increasing the pressure; but this increase is not constant and differs considerably for different types of boilers.

An existing paper mill recently decided to bring its steam power plant up-to-date and adopted the following solution:—The electric current required was obtained from a 400 kw. hydro-electric plant belonging to the paper mill and any additional current was taken from outside sources. Two paper machines, in the case of the second one only the variable part, are driven by hydraulic turbines. The other two paper machines are driven by steam engines, the constant part of one of these having a separate steam engine drive. All five steam engines work with an admission pressure of 118 lb. per sq. in., admission temperature of 482 deg. fahr. and a back pressure of 10 to 15 lb. per sq. in. The exhaust steam, after it has been freed from oil, is used for heating purposes. Any extra demand, and also the heating steam for both the hydraulically driven paper machines, is supplied from the old steam boiler working at a pressure of 85 lb. per sq. in. Boilers working at 130 lb. pressure supply the steam for the steam engines, about 8800 to 12,100 lb. per hr. while the boilers at 85 lb. pressure cover the requirements for heating steam, also 8800 to 12,100 lb. per hour.

As the hydraulic power plant and the existing boiler plant are no longer sufficient for the present paper mill and the cellulose works which will be built later, it was decided to install a primary high-pressure steam power plant. Fig. 2. The electric energy must be supplied by the Sulzer primary en-

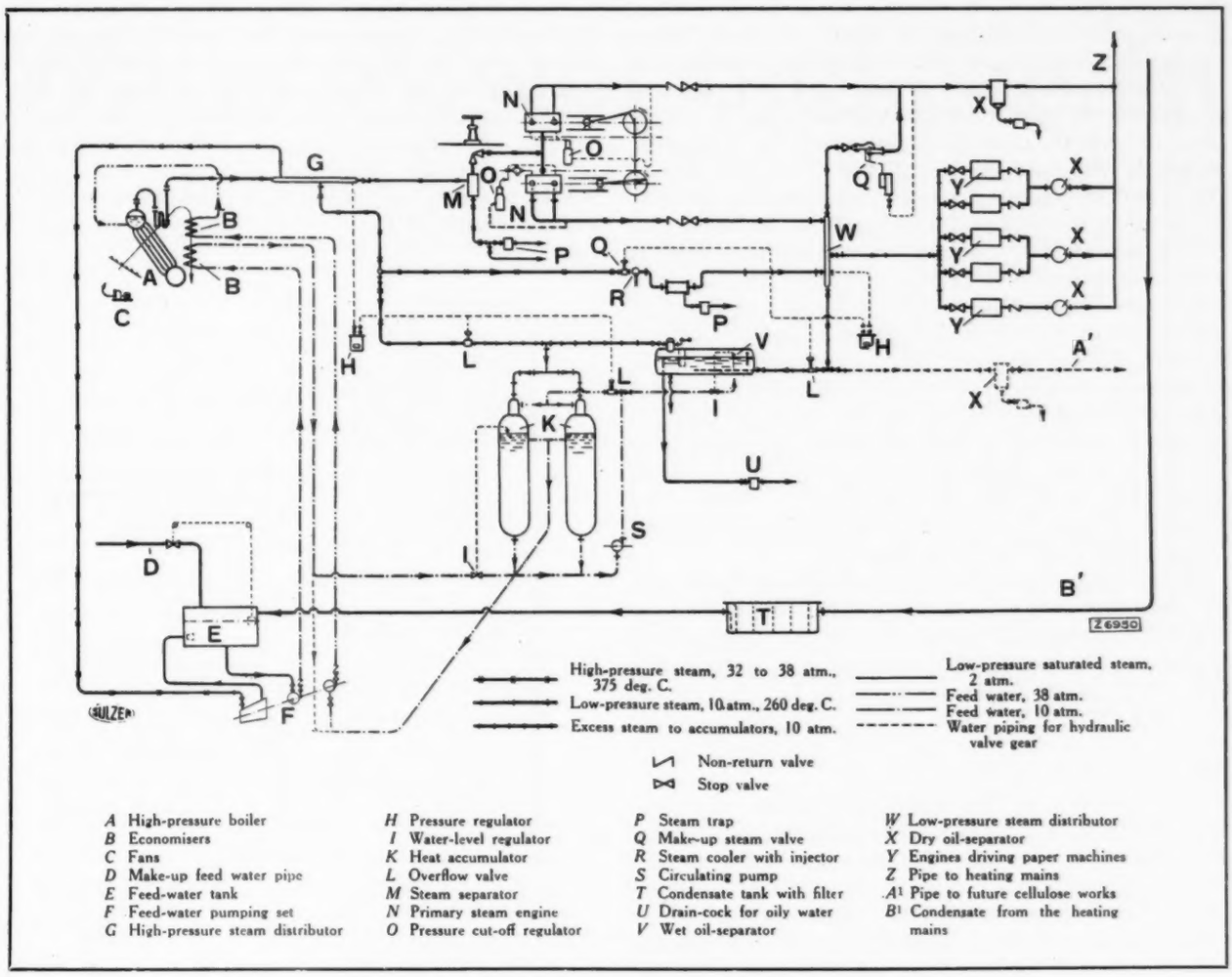

High-pressure steam, 32 to 38 atm., 375 deg. C.
Low-pressure steam, 10 atm., 260 deg. C.
Excess steam to accumulators, 10 atm.
Low-pressure saturated steam, 2 atm.
Feed water, 38 atm.
Feed water, 10 atm.
Water piping for hydraulic valve gear
Non-return valve
Stop valve
A High-pressure boiler
B Economisers
C Fans
D Make-up feed water pipe
E Feed-water tank
F Feed-water pumping set
G High-pressure steam distributor
H Pressure regulator
I Water-level regulator
K Heat accumulator
L Overflow valve
M Steam separator
N Primary steam engine
O Pressure cut-off regulator
P Steam trap
Q Make-up steam valve
R Steam cooler with injector
S Circulating pump
T Condensate tank with filter
U Drain-cock for oily water
V Wet oil-separator
W Low-pressure steam distributor
X Dry oil-separator
Y Engines driving paper machines
Z Pipe to heating mains
A1 Pipe to future cellulose works
B1 Condensate from the heating mains
SULZER
Z 6950

Fig. 2—Heat flow diagram of paper mill power plant.

gine plant as far as possible to suit the existing arrangements in the works, a fall of pressure from 450 lb. per sq. in. at 710 deg. fahr. to 30 lb. per sq. in. saturated steam in the other half of the machine. The exhaust steam at 145 lb. pressure is led as working steam to the five existing steam engines, so that this part of the plant is regulated in accordance with the steam consumption of the low-pressure steam engines. The exhaust at 30 lb. pressure from the primary engine is utilized directly as heating steam for various purposes. The governing of the second half of the plant depends therefore on the requirements for heating steam 30 lb. per sq. in.

When the plant is fully utilized, the primary engine develops normally about 720 kw. (maximum 880 kw.) while the corresponding quantities of steam are:—at 145 lb. pressure and 490 deg. fahr., normally about 8800 to 11,100 lb. per hr. (maximum 15,500 lb.), and at 30 lb. pressure saturated steam, normally about 8800 to 11,100 lb. per hr. (maximum 15,500 lb.)

The high pressure steam is raised in two single-bank upright water-tube boilers (each of 2950 sq. ft. heating surface), 500 lb. working pressure and 750 deg. fahr. steam temperature, with a two-stage economizer plant at 145 and 545 lb. pressure respectively for preheating the feedwater from 130 to 195 deg. fahr. in the first stage and from 350 to 410 deg. fahr. in the second stage. The quantity of steam raised by each boiler is 20,300 lb. per hr. under normal conditions and 26,400 lb. per hr. maximum.

The feedwater constant-pressure heat-accumulator makes it necessary to divide the economizer and the feed pumps into two stages as mentioned above. This accumulator works on the following principle: if the demand for steam at 145 lb. per sq. in. falls, the superfluous steam at 145 lb. pressure is used to raise a corresponding quantity of the feedwater contained in the accumulator to a higher temperature by means of condensing nozzles. The water level in the accumulator is kept constant and the feedwater is led off at the highest point, in order to have the temperatures of the water constant. The storage capacity has been calculated as sufficient to take the full boiler output for about 30 minutes. By this means, in addition to complete utilization of the steam, a constant and therefore economical loading of the boiler is obtained.

A further combination between power and heat

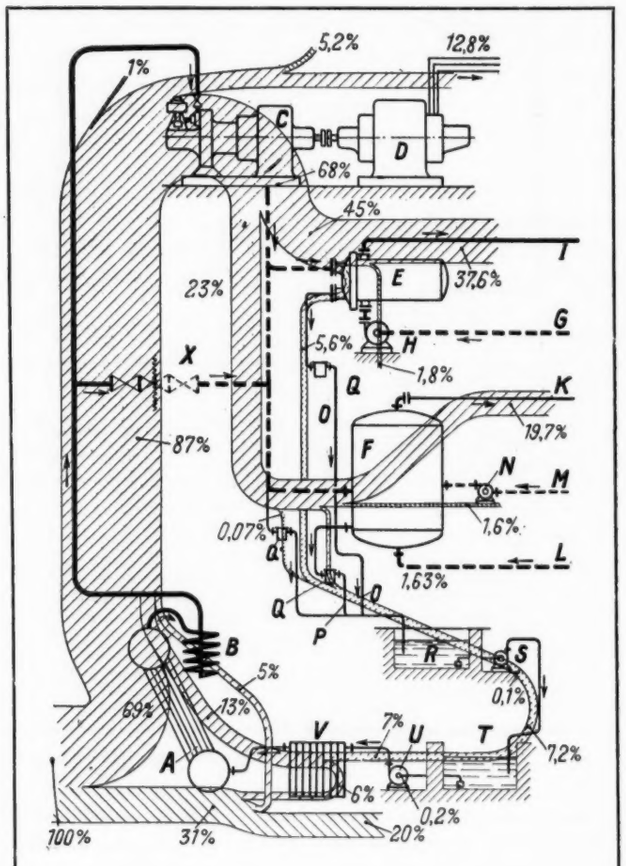
requirements is to be found in district heating plants. The calculation of such plants is based exclusively on the amount of heating required, according to the nature of heat and the physical properties of the medium transmitting it. Heat can, of course, now be transmitted by means of steam or water to comparatively great distances—up to several miles—without incurring much loss; but such a method will never attain the flexibility and handiness of electric transmission. This is why it is desirable to choose the least variable factor. The amount of power generated is only as much as can be obtained from the steam needed for central heating or other heating purposes. Fig. 3, illustrates such a plant diagrammatically, showing how the heat contained in the fuel is utilized. Steam is raised at a high pressure and high temperature in the boiler and passed to the turbine, where it is used to produce mechanical energy and expands down to a convenient low pressure for utilization in the heat exchangers.

It is here assumed that all the exhaust steam can be used for heating purposes, two-thirds for the district heating and one-third for the district hot-water supply plant. An arrangement is generally made with some electricity works to take the superfluous power. In many plants the hours when power and heat are required do not coincide, so that the heat must be stored.

An example of thorough utilization of waste material is given by the refuse destructor plant at Zurich. The amount of refuse collected in the town of Zurich in the course of a year amounts at present to above 40,000 tons. This is burned on special grates under a steam boiler and the steam is used for driving two turbo-electric sets. The exhaust steam from the turbines is utilized for heating several buildings in the neighborhood of the railway station, for which purpose five counter-current apparatus are installed in the power house.

The methods adopted for disposing of surplus energy in power plants have greatly changed with the increase in the number of ways in which it can be utilized. Formerly the chemical industry was depended upon as the principal consumer of current at hours when the works were lightly loaded. Cheap current during the night is also often used in ice factories. In addition to that, in some districts a considerable amount of electric energy is now used during the night for domestic hot-water accumulators and steam storage boilers; this has been brought about by offering special rates. Also electric boilers are especially suitable for working with current during the night, as their regulation is absolutely automatic, making attendance unnecessary. They are consequently often used to raise steam for use during the next day, often being worked in conjunction with steam accumulators.

In consequence of the various ways in which surplus energy may now be disposed of, steam electricity works have generally little difficulty in disposing of current during the night, so that there is practically no longer any surplus energy. On the other hand, the conditions under which hydro-electric stations operate in the course of a year are very variable. In summer they have large quantities of water at their disposal, a large part of which must flow away unutilized; in addition to that, the demand for current in summer is less than in winter. By utilizing these quantities of water and making suitable arrangements with other electricity supply companies, it is possible to generate energy which can be usefully employed in electric



A High-pressure boiler plant	*L* Cold water main
B Superheater	*M* Return pipe from district service-water supply
C Steam turbine	*N* Circulating pump for service-water
D Dynamo	*O* Condensate pipes
E Heat exchange apparatus for the district heating	*P* Condensate pipes
F Heat accumulator for the district service-water supply	*Q* Steam trap
G Return pipe from the district heating	*R* Condensate tank
H Circulating pump	*S* Condensate pump
I Flow pipe to the district heating	*T* Feed-water tank
K Flow pipe to the district service-water supply	*U* Boiler-feed pump
	V Economiser
	X Live-steam pressure reducing valve

Fig. 3. Heat balance diagram for combined heating and power plant.

boilers, especially in districts to which coal must be transported from a great distance.

A specially noteworthy method of utilizing surplus energy is in the dry-cooling of coke in gas-works, coke-oven plants etc. The incandescent coke from the retorts, which hitherto has been exclusively quenched with water, is cooled in a special plant by means of inert gases circulated

(Continued on page 54)

Water Power and Steam

By Dr. JULIUS KLEIN
Assistant Secretary of Commerce

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This is a reprint of a radio talk given by Dr. Klein through the courtesy of the Columbia Broadcasting System, May 31, 1931. Not only is it a highly interesting discourse on the present-day use of electricity and its methods of generation, but it is significant in a large sense of the viewpoint of those well informed as to the relative status of water power and steam. Dr. Klein's interpretation of this question is summed up in the following sentence quoted from his talk, ". . . in the actual production of electric power today, steam is a vastly more important factor, and I venture to say that it will continue to be so until mankind has discovered some entirely new mehod of utilizing natural energy."

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IN this electrical age it may come as something of a shock to some of us to realize that we are more dependent upon those two ancient servants of man, fire and water, than the human race has ever been at any previous stage of its development. The silent, omnipresent force of electricity that today does so much of our work for us, from heating our curling irons and toasting our bread, to operating the mightiest machinery of our factories, may seem to have little kinship to the forms of power on which our ancestors had to depend. Yet electricity, in the forms in which we use it, does not create itself spontaneously. Even Benjamin Franklin's historic experiment with the kite and lightning did not, unfortunately, lead the way to our being able to snatch from the clouds any useful quantities of electricity. Nature, even now, does not subscribe to the principle that mankind should be given something for nothing. Every unit of electricity used in our homes and industries is nothing more than a transformation of the more primitive forms of energy found in fire or water. But what amazing strides have been made recently and are being made right now in harnessing these prodigious forces of nature! As Herbert Hoover said, when he was Secretary of Commerce, "We are in the midst of a great transformation in the development of electrical power—it amounts almost to an industrial revolution, for it bears upon its wings the most profound advance of American industry in a generation. It is reducing the burden of human toil, it is increasing productivity, it is bringing increased comfort to our people."

In the present-day phases of this vast "industrial revolution," as the President calls it, one major question seems to be: Is the water power of a nation the paramount power factor, or can we still depend primarily on steam, as we have for decades? The utilization of the energy in falling or flowing water has been known for centuries. The ancient moss-covered mill wheels that used to be such common adjuncts of our country streams were the direct forebears of the great turbines of our water powers of today. Steam power, on the other hand, is a mere baby, in the historical sense, for it was not until the latter part of the Eighteenth Century that the experiments of James Watt permitted its application to industry. Yet, oddly enough, many of us have been regarding steam engines as, somehow, old-fashioned and even antiquated as compared with modern water-power development. In this modern age it is water power that seems to offer infinite possibilities. Our water falls and rivers will run on forever without human stimulation, and, therefore, will they not be a perpetual source of cheap power? In the utilization of this natural resource, the power of falling water, there is much that captivates our fancy today, just as our grandchildren, perhaps, may someday be intrigued with new discoveries permitting the practical application of solar energy, the forces of the tides, and, perhaps, even the energy of the atom.

So great is the hold of water power on our imaginations that it has become, from time to time, an "issue." But who can conceive of any one making an "issue" of steam, to rank with such social and economic questions as the tariff, naval limitation, or even prohibition? No; steam power is too commonplace to be discussed in our legislative halls and pullman smoking rooms. Yet, in the actual production of electric power today, steam is a vastly more important factor than water, and I venture to say that it will continue to be so until mankind has discovered some entirely new method of utilizing natural energy.

I have nothing to say about water power as an "issue." I do want to discuss its present relative status as compared with steam as a producer of electricity. Let us get this much-discussed matter of water power in its proper perspective.

Somehow or other, there seems to be something much more picturesque—more conducive to oratory—in the building of great dams and reservoirs than in the setting up of a factory full of furnaces, boilers, and steam turbines. And yet, there is hardly a water power project developed today that does not require for its economical operation the construction beside it of a steam plant (chiefly to carry on when the water runs low) and the productive capacity of that steam plant often is at least as great as that of its water-power twin. The development of a water-power site is certainly a more picturesque undertaking than the erection of a coal, oil, or gas-burning power plant, but, even so, I believe that a good part of the popular interest in the hydro plant is due to our having failed to change our perspective in the last twenty years, during which the technology of steam power has been making amazing strides.

The possibility of applying the principle of the old wooden water wheels to the generation of electric power was seen as soon as the first electric-light plants were constructed. In 1882, Thomas A. Edison set up the first electric-power "central station" in the world, in New York City. Think of it! That is less than 50 years ago. It was operated by steam, but a few months later another small plant was constructed in Appleton, Wisconsin, and operated by water power. From that day to this the two sources of energy have been utilized in the production of electric power. It is in the last twenty years, however, that the use of water power has expanded most rapidly.

Back in 1910, the efficiency of water wheels was nearly as high as it is today in transforming into electricity the energy in falling waters. It has progressed in those twenty-one years from capturing about 90 per cent of the total available energy to 93 per cent. (By the way, do not let those engineers fool you when they talk about "water wheels." It may be the same word that was used for that familiar moss-covered contraption down by the old mill stream, but you would never recognize the old wheel in its modern incarnation. A water wheel today is a complicated apparatus that may make as many as 3,000 revolutions per minute and is whirled around by a stream under a pressure that may be as high as 2,000 pounds to the square inch. Such a jet of water is so solid that you cannot cut through it with an axe: The axe would be jerked right out of your hands if you tried it!)

Steam power generation, twenty years ago, was comparatively expensive. The most efficient plants then could get no more than 15 per cent efficiency from their fuel. That is, 85 per cent of the energy in each pound of coal burned was lost before the power became available in electricity at the switchboard. So there seemed to be reason to believe that the future of world's power development lay more in hydro plants than in steam.

But here is an important fact for us consumers and taxpayers to remember. It has always been much more expensive to develop a water-power system than to set up a steam plant. With the efficient methods of today a water-power system of average merit, including transmission, may range in cost between $200 and $500 per horsepower of capacity. But a steam turbine plant which can be located at the center of use where no costly system of power transmission is required, will cost not more than $100 per horsepower. So, as the most strategically located water-power sites were developed, and it became necessary to transport their product over longer and longer transmission lines, this matter of capital costs became more and more important. The energy of falling or flowing water may have been stored there by a beneficent Nature, but Nature is not of much help when it comes to converting that energy into usable form and delivering it where it is needed. Before a single unit of electricity can be turned out, extensive land and water properties and rights of way must be bought; dams, reservoirs, pipe lines, long-distance power lines, etc., must be built and installed. These things can not be done overnight, and interest accumulates rapidly during construction.

Once in operation, however, a hydro-electric plant costs less to operate than would a steam plant of the same capacity. And, a few years ago, this difference in operating costs was sufficiently great to justify a very extensive development of conveniently located water-power sites, despite the disproportionate outlay of capital involved.

But in recent years some important things have begun to happen. Engineers and scientists have been devoting rather concentrated efforts toward increasing the efficiency of steam plants. The use of powdered coal, fed into furnaces by air blasts, permitted the efficient consumption of cheaper fuel, whose quality had previously been considered too low for industrial requirements. Super-heated steam added its share of increased efficiency. Vast improvements were made in the designing of steam turbines. It was not so long ago that a steam pressure of 100 pounds to the square inch was considered high; now 1,000 pounds is quite usual and pressures as high as 3,000 pounds have been used experimentally. Boiler efficiency was greatly increased, and all sorts of minor technical improvements were made in the construction of pumps, condensers, and other auxiliary equipment.

As a result, today's steam plant is more than twice as efficient as that of only twelve years ago. Now, more than 30 per cent of the energy in the fuel burned by a steam power plant reaches the switch board. And the end of these improvements is not yet in sight. Thirty per cent may not sound like an impressive figure, even compared with the 15 per cent efficiency that was attained back in the days when water power was as exciting to the engineer as it is now to the political orator, but let us see just what it means in other terms.

In 1919, to produce one kilowatt hour of electricity by steam, it was necessary to burn 3.2 pounds of coal (or its equivalent in oil or gas). In 1930, in the steam plant of only average efficiency, 1.6 pounds of coal, just one-half the earlier figure, produced the same amount of electricity. Last

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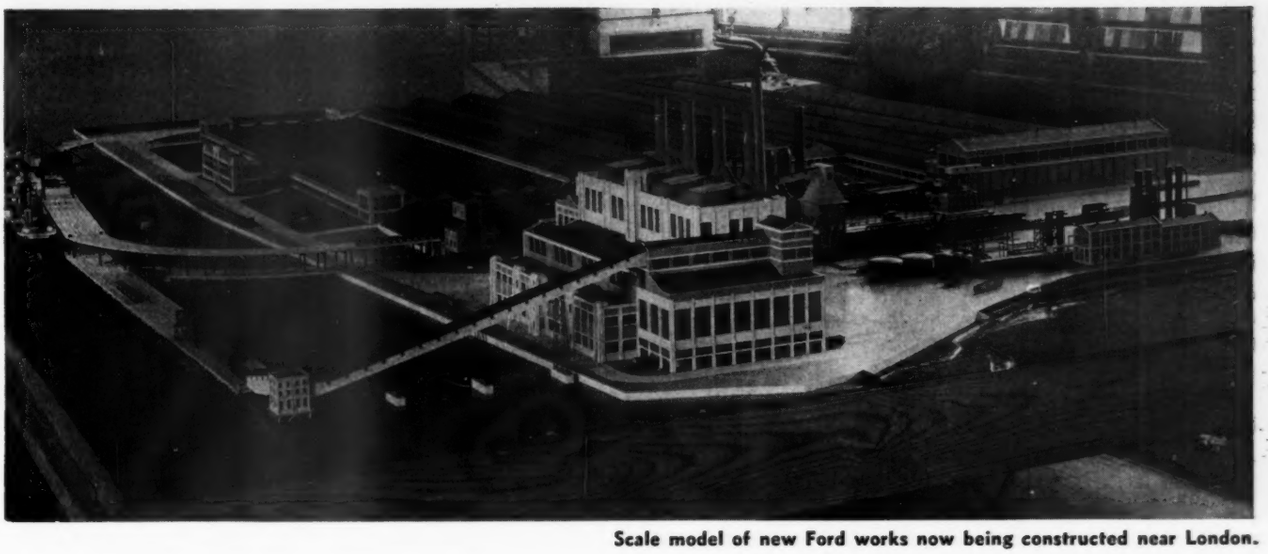


Scale model of new Ford works now being constructed near London.

Scientific Coordination of Fuel Utilization

By DAVID BROWNLIE
LONDON

Various developments such as the recovery of by-products from coal before its use as fuel, the recovery of sensible heat from hot coke, and the use of steam at high pressure for power generation and its subsequent use at lower pressure for other purposes, are being coordinated in connection with large industrial and power projects wherever practicable. The economies to be derived from such practice are of sufficient importance to warrant thorough analysis wherever the opportunities for combining these developments exist. In his discussion of this subject, the author presents a preliminary description of the new Ford plant, now being constructed near London, as an outstanding example of this modern trend.

A NOTABLE development in the past few years is what may be termed, for want of a better definition, scientific coordination in the use of fuel so as to improve the overall efficiency of a number of related processes or operations. Two of the chief fields in this connection are steam and power generation and the manufacture of iron and steel.

It is now being realized more and more, for example, that the inherent defects in the ordinary steam-driven power station with condensing steam turbines are the use of raw coal in enormous quantities, and the fact that from 50 to 60 per cent of the total heat in the coal is lost in the condensers, through which 450 to 500 tons of cooling water has to be passed for every ton of coal burned.

The ideal is improved scientific coordination, that is, for example, a combination of low temperature carbonization, with combustion of the coal, and the recovery of the valuable by-products, together with the generation of power with high-pressure steam and the sale of low-pressure steam or hot water to surrounding establishments so as to put to good use the principal part of the 50 to 60 per cent of the heat ordinarily lost to the condenser.

We have of course not yet reached this ideal, but already a considerable number of power stations in the United States are selling hot water and steam on the most scientific lines, and in a number of other cases attempts are being made to combine low temperature carbonization and combustion of fuel for steam generating purposes.

One of the most remarkable power stations in

the world in this connection is Langerbrugge, near Ghent in Belgium, belonging to the Centrales Electriques des Flandres et du Brabant. This station represents the very latest principles of steam generation, with a Benson super-pressure steam generator operating under the actual critical conditions of 3200 lb. per sq. in. and 716 deg. fahr. steam temperature, the steam being superheated to 840 deg. fahr., and utilized in small high-speed, back-pressure turbines exhausting to ordinary back-pressure turbines which also use live steam from medium-pressure boilers, exhausting to low-pressure condensing steam turbines after a certain amount of steam is extracted for sale.

Adjacent to this station are over 30 different factories, most of which take bulk electricity. There is also an associated firm, called Gandcharbon, which operates a Salerni low temperature carbonization plant with a capacity of 40 to 50 metric tons of coal per 24 hours, and a Thyssen or Thyssen-Roser plant with two retorts each of 100 metric tons per 24 hours capacity. Bituminous coal is carbonized under very low temperature conditions, generally about 750 to 840 deg. fahr., and the whole of the smokeless fuel is burned in the adjoining power station on chain grate stokers or by pulverized fuel equipment, a considerable part of the gas also being used as fuel.

All the low temperature tar from the Salerni and Thyssen plants, is taken by another company, known as the Belgian Cracking Company, which has a normal throughput of 40 tons of tar or crude oil per 24 hr., together with a refining plant for the light oil or motor spirit of 30 tons per 24 hr., using the Dubbs cracking plant with a standard capacity of 300 barrels in this time. The results are stated to be extremely good.

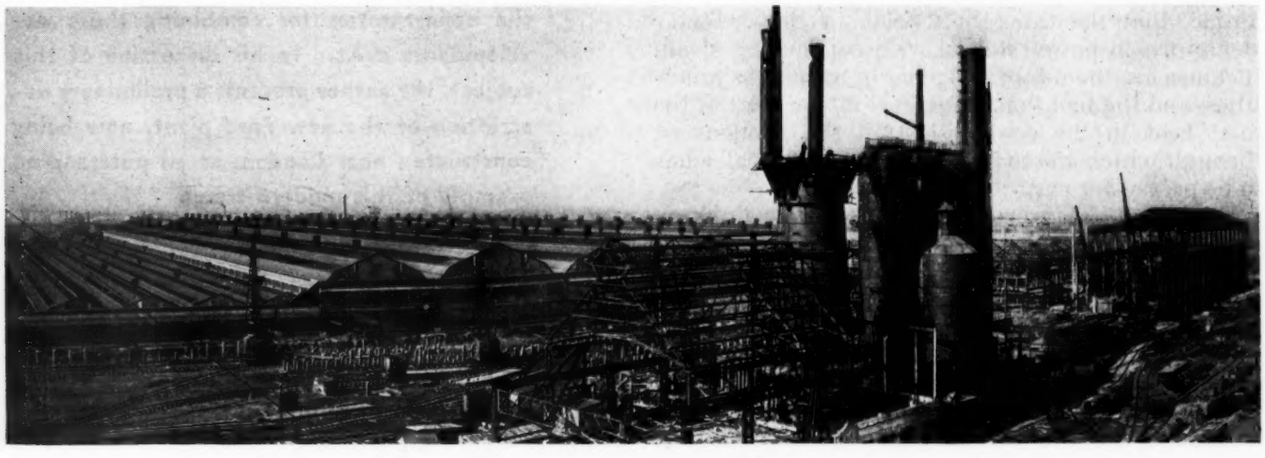
The iron and steel industries present some striking possibilities for scientific coordination in the use of fuel, with the grouping together of blast furnace plant, metallurgical furnaces of every description, coke oven plant, and power stations, so designed as to utilize to the fullest extent the whole of the available gaseous, liquid, and solid fuels, that is including the blast furnace gas, coke oven gas, refuse coal from the washing plant, coke breeze, and waste heat from the various furnaces.

There are a number of examples in the United States of establishments operated more or less on these scientific lines, and it will be remembered that the writer described some time ago, in an article published in COMBUSTION, the similar principles that are being adopted in the iron and steel industries of Lorraine, especially as regards the co-operative generation and sale of surplus electricity from the steel works by means of a special company formed for the purpose, the Société Electrique de la Sidérurgie Lorraine of Nancy. This company operates an extensive system of overhead transmission lines, sub-stations, and power stations and utilizes the blast furnace gas, coke oven gas, and low-grade solid fuels by means of pulverized fuel firing.

It is the principal object of the present article to describe one of the latest and most remarkable examples of coordinated fuel utilization, i.e., the new Ford Works at Dagenham on the Thames, near London, the construction of which was officially commenced on May 17, 1929, with completion expected at the end of the present year or early in 1932. Full information cannot yet be obtained, since of course the various plants concerned with fuel and power are not completed, and in some cases the erection is only just begun. The whole matter, however, is so interesting and important that it merits a preliminary description which the author is able to give through the courtesy of the Ford Motor Co., Ltd., London.

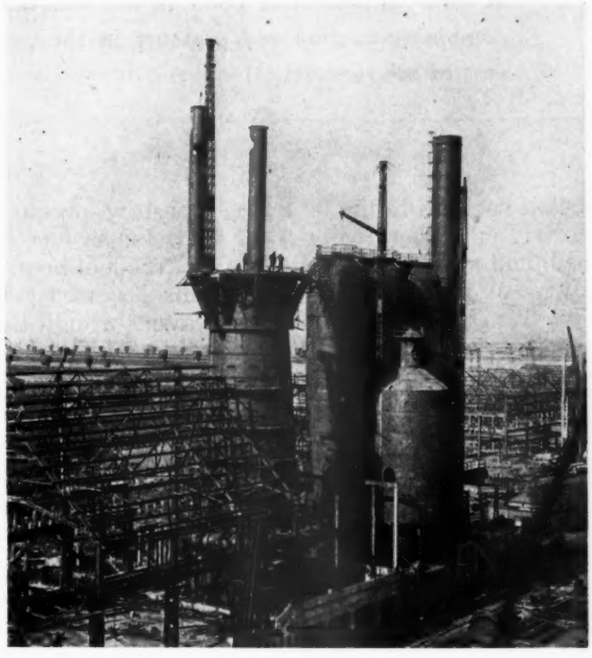
This works will undoubtedly constitute one of the largest, most important, and most scientifically organized industrial establishments in the world, with an eventual calculated output of 200,000 automobiles per annum.

The whole area of land purchased on the Thames is 500 acres, of which 270 acres are reserved for industrial developments, the present site in active use being about 110 acres, with a frontage of 2400 ft. on the river. Essentially the scheme consists of a huge jetty 1800 ft. long and 51 ft. wide, projecting out into the Thames, which alone has cost about $1,650,000, a block of offices on the river front 200 ft. long by 50 ft. wide, a space of 200 ft.



Panorama view of new Ford works showing blast furnace plant in right foreground.

by 400 ft. for a garage, an assembly building 1000 ft. long by 300 ft. wide, a manufacturing building also 1000 ft. long by 300 ft. wide, a foundry and machine shop 1260 ft. long by 300 ft. wide—these three shops together alone occupying about 20 acres, blast furnace plant, coke oven plant, and a power station on the most advanced lines, including boilers to operate at 1200 lb. per sq. in. pressure, with utilization not only of blast furnace gas, coke oven gas, and pulverized fuel, but also a huge amount of household refuse which is to be brought down the Thames from London in barges. The east part of the jetty is reserved for the handling of



Another view of blast furnace plant of new Ford works.

this household refuse, delivered from the barges. The refuse will then be taken by conveyors to a transfer station for separation of material such as tins and bottles, with final delivery to the bunkers on the top of the power house.

The west end of the jetty is for the outward shipment of the automobiles and parts, the average depth of the water at this point being 20 ft., so that two 6000-ton ships can come alongside. The center part of the jetty is for vessels bringing coal and ore and limestone for the blast furnaces and coke oven plants.

Undoubtedly so far as fuel technology is concerned the question of burning large quantities of household refuse for steam and power generation is one of the most important aspects of the Ford Works at Dagenham, and the results obtained will be awaited with great interest. Incidentally it may be stated that the production of towns' refuse averages ¼ ton per annum per capita, so that Greater London, for example, with a population of over 7,000,000, turns out every year about 1,750,000 tons of refuse. So far the efficient use of this material is an unsolved problem, the nature of which will be rendered evident by the fact that in London the average cost is $1.44 per ton for disposal only, that is by taking it down the river and throwing it into the sea or on the Thames mud flats, or piling it up in vast dumps. It is true, of course, that in London, as in other large towns, a certain amount of such refuse is consumed, but the total of such consumption is almost negligible, and this outstanding problem is deserving of far more serious consideration than it has received. Certainly, therefore, the Ford Company may be considered noteworthy pioneers in this field, as they have been in many others in connection with fuel technology.

The power plant at Dagenham will contain three 1200-lb. pressure boilers, each with an evaporation of 200,000 lb. per hour and two 200-lb. pressure boilers for general process work. Space will be provided for one additional high-pressure boiler and one additional low-pressure boiler, making a total of seven units. As regards the generation of power, in addition to the 30,000 kw. British Thomson Houston turbo-generator, which is of the 3-stage type running at 3000 r.p.m., there will also be a house service set of two steam-turbine-driven blast furnace blowers.

Also each of the three main buildings is supplied with electricity, gas, steam, water, and compressed air by means of a large tunnel 1060 ft. long, 12 ft. 6 in. wide, and 8 ft. 6 in. high, with offshoots to every part of each building.

The blast furnace plant is of Freyen design, built by Ashmore Benson Pease & Co., Ltd., of Darlington, and has a nominal capacity of 500 tons of pig iron per 24 hr., with three Strack stoves and Dorr thickener for the reclaiming of fine iron dust. There is also an improved sintering plant, the first of its kind in Great Britain, and all arrangements have been made for the addition of a second blast furnace when necessary.

It is highly interesting to point out that this is the first blast furnace that has been erected in the south of England for a number of centuries, in fact since about 1450 when the first blast furnace in the British Isles was erected at Buxted in Sussex by a Frenchman. The blast furnace was of course invented in the Low Countries (Holland and Belgium) in the Namur area about 1320, replacing the old-fashioned intermittent oven or furnace comparatively low in height, made of clay, which had done duty for untold centuries previously and is still operated today by various savage tribes.

It was not until the invention of the blast furnace with continuous operation that the science of casting or founding originated, due of course to a supply of iron being made available in the highly liquid or molten condition which could be poured. It is for this reason that the French term is "Haut-fourneaux" and the German "Hochofen," denoting the relatively great height of the first blast furnaces as compared with the previous intermittent method of smelting iron.

The iron industry first flourished in Great Britain in Sussex where it remained until all the trees

(Continued on page 51)

Steam Jet vs. Vacuum Ash Conveyors

By EUGENE HAHN

Hahn Engineering Co.
New York, N. Y.

The author analyzes the operation of both types of conveyors and reaches a conclusion which is strongly in favor of the steam jet conveyor in which the steam jet is admitted at some intermediate point in the line thus combining suction and pressure in the process of ash removal.

SIMPLICITY in construction and operation is by far the most important requirement with any ash conveyor.

The steam-jet conveyor is but a simple ejector of from 4 in. to 8 in. diameter. Provided its layout is such, that the jet or jets of steam injected between its two ends are given an opportunity to become efficiently expanded—so that their heat-energy, like in the steam engine, is economically utilized—and provided that the pipe-line is permanently tight at its many joints, the ejector type steam-jet conveyor is highly efficient.

What remains to be considered with a satisfactory steam-jet conveyor is the low cost of maintenance, achieved through properly placed and sufficiently hard liners, that are made readily accessible, and the elimination of dust at the discharge-end without contraptions that are bound to create back-pressure in the tank and thus impair the efficiency of the conveyor.

With permanently tight joints there is no occasion for objectionable noise due to the operation of the conveyor outside of the boiler room. The swishing sound of inrushing air at the ash-intakes can surely not be objected to in the boiler room.

With a steam-jet conveyor, that is economical in its steam consumption, less moisture enters the tank than is contained in quenched ashes handled by various mechanical conveyors. Consequently it is unfair to blame efficient steam-jet conveyors with causing packing or freezing in tanks when they contribute no more if as much, to this condition than other methods of ash conveying. Unfortunately there seems to be an unwarranted notion, that even efficient steam-jet conveyors are the worst offenders in this respect.

The average vacuum conveyor can not compare in simplicity with the steam-jet type, because of its requirement of an air-tight receiving tank as part of the apparatus. To maintain a steel-plate tank air-tight under the destructive action of ashes is anything but simple. A concrete tank may be more easily maintained in an air-tight condition, but its proper design for discharge-efficiency is rather expensive, besides being cumbersome to build in many instances.

The original means for producing the required partial vacuum in the tank was a positive-pressure blower, or rather two sets of blowers, as one of them had to be in reserve due to the frequent breakdowns of the operating unit. This becomes evident from the fact, that the air drawn through the blower is bound to contain a quantity of fine ashes, which must be removed at frequent intervals, as the housing of the blower becomes clogged with it. Screens, washers and the like have little chance against the sand-blast action of fine ashes at high velocities.

The alternative of a jet or jets of steam to produce the partial vacuum in the tank through exhausting the air from it, is generally recognized to be very wasteful as against the use of the blower. This must be evident in view of the fact, that such jet or jets of steam exhaust into the atmosphere at high pressures—from 100 pounds upward —just like a locomotive whistle with no semblance of efficiency.

While thus the use of blowers is prohibitive because of their high maintenance, the waste of high-pressure steam militates against the employment of jets for producing the required partial vacuum in the tank.

The more efficient method of using blowers has its justification in the handling of dust, grain or of similarly light substances, but its periodical revival for the handling of abrasive and corrosive ashes has repeatedly proved its being unfit for the purpose. On the other hand the inefficient method of using steam jets to produce vacuum in a tank is being looked upon with increasing aversion.

Claims are being made, that for the displacement of a given volume of air a jet of steam discharging into the atmosphere is more efficient in a vacuum conveyor, than the same jet of steam discharging within the confines of a steam-jet conveyor, wherein back-pressures exist. The apparent advantage of the former is however more than offset by the attending conditions of the average pneumatic conveyor. For one, the discharge of a jet of steam at 100 lb. pressure, or often well over, in-

to the atmosphere causes such great noise, that it is objectionable in practically every case.' Consequently such a jet is usually discharged into a muffler, also called a silencer, or through an ample pipe into the stack, if the latter is not too far from the tank. Accordingly the same back-pressure condition has been created, as in the steam-jet conveyor. However, by either method of eliminating the noise of the exhaust, the energy released in the process of reducing the steam pressure is completely wasted. As against this condition, the expansion in the riser of the steam-jet conveyor pushes the ashes and clinkers before it—very much like a piston in a cylinder after passing the cut-off line—so that the exhaust from the jet has been put to the useful work of propelling the ashes and clinkers upward in the riser.

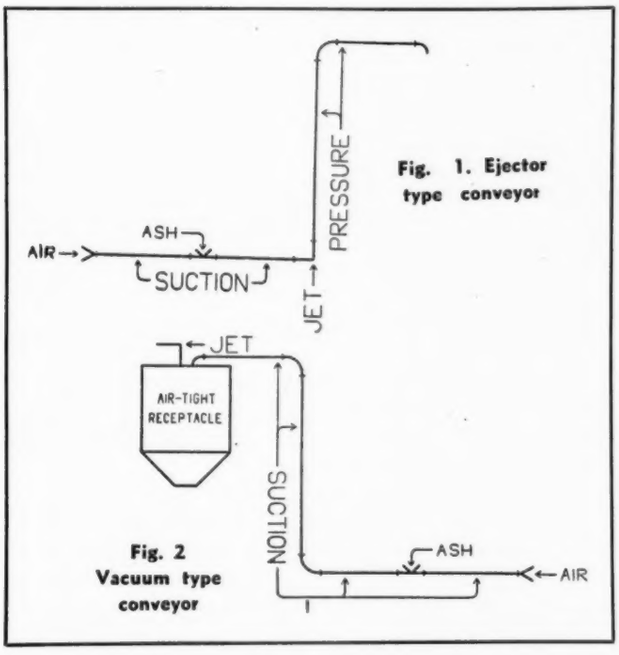


Fig. 1. Ejector type conveyor

Fig. 2 Vacuum type conveyor

Ashes are obviously considerably heavier than air and their friction against the walls of the pipeline is much greater also. It is a fallacy therefore to refer to the discharging of air only in pneumatic conveyors, when the problem at hand is the propulsion of ashes and clinkers through them. If the latter can be sucked through half of the pipeline and the function of pushing through the other half is practically a by-product of the function of suction caused by the expanding and rising jet of steam (Fig. 1) then it becomes very evident that overcoming the weight and friction of the same volume of ashes and clinkers for the full length of the pipe-line by suction only and without utilizing the force of the expanding steam to push the ashes and clinkers through part of the conveyor (Fig. 2) is a task requiring correspondingly more steam. Other disadvantages of Fig. 2 are the necessity of silencing the high-pressure exhaust and the fact that a leak in any of the joints affects the whole pipe-line, while in Fig. 1 a leak affects either the suction line or the pressure side only.

Scientific Coordination of Fuel Utilization

(Continued from page 49)

were cut down. It then migrated to Coalbrookdale in Shropshire, spreading from there over various parts of the country, chiefly in the north and the southwest. The Ford Company has therefore altered the whole situation again from the territorial point of view in erecting this blast furnace in the south of England.

The necessary yard to take the material as delivered from the jetty is divided into three parts and has a total storage capacity of 34,200 tons of coal, 122,000 tons of ore, and 11,500 tons of ironstone, being served by an electrically controlled conveyor bridge. Approximately 10,000 tons of coal, ore, and limestone will be required per week.

The coke ovens are of the Wilputte design supplied by the Coppee Company, the equipment consisting of 45 ovens with a throughput of 800 tons of coal per 24 hr. It is claimed that the coal and coke handling plant of this Wilputte installation will be the finest in the world and almost completely automatic in operation throughout. The by-product installation is also on the latest lines, and it is the intention to use the recovered benzol for driving away the Ford cars.

Another notable feature is that the plant will have the first dry quenching coke equipment in the British Isles. It is estimated that this plant will generate steam from the gases released in cooling the coke at the rate of about 15,000 lb. per hour.

This then is another aspect of fuel technology in which little progress has been made as nearly all the coke-oven plants in the world are still discharging a vast number of tons of white hot coke per annum and cooling it merely by quenching with cold water, thus wasting all the sensible heat. The actual results obtained at Dagenham will, therefore, be awaited with great interest.

In concluding this article, it may be of interest to give some statistics on the project. From 15,000 to 20,000 men have been employed on this job for a considerable time past; 11 miles of standard gage railway have been laid; more than 450,000 cu. yd. of earth have been dug out, largely used to make the railway embankments; during the past twelve months over 11,000 concrete piles have been driven down into the solid ground below, in some cases to a depth of over 80 ft., the ground generally being of a swampy and difficult character; altogether about 13,800 of these concrete piles will be used, each one of which has its history recorded on a card index in detailed fashion. Some quantitative items of interest from a construction standpoint are,—92,000 tons of concrete, 2224 miles of reinforced wiring, and 8,000,000 wooden blocks to cover the concrete floors, as well as 13,500 tons of steel in the buildings and nearly 14 acres of glass roofs, including 3 miles of gutters and 6 miles of catwalks with combined handrail and water pipe.

The Combustion Characteristics of Fuel Oil

By B. J. Cross

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While petroleum in its crude form is sometimes used as a fuel, the term "fuel oil" is usually considered to include only "topped" crude or crude oil from which the more volatile constituents have been distilled. The chief sources of fuel oil for use in the United States are the fields of California, Texas and Mexico. Oil from the latter field contains only relatively small quantities of volatile oils and is often used in the crude state as fuel.

The principal requirements of a fuel oil are described by its viscosity and its flash point. The viscosity of an oil is a measure of its fluidity. It is determined by the time required for a given quantity of oil to flow through a small orifice and is reported in seconds. Viscosity decreases with temperature and oils are usually heated to a temperature of 150 deg. to 250 deg. fahr. to render them sufficiently fluid so that they may be atomized under pressure in the burner. Oils from the Mexican fields have a high viscosity and often must be heated before they can be pumped from storage tanks.

The flash point of an oil is the temperature at which inflammable vapors are given off. It is determined by heating the oil at a steady rate and testing for the ignition point of the vapor at short intervals with a small flame. For considerations of safety, the low limit of the flash point is usually set at 150 deg. fahr. The viscosity and the flash point must be considered together. The flash point should be higher than the temperature to which it is necessary to heat the oil to get the required fluidity. For the same safety requirement low viscosity oils may have a lower flash point than oils of high viscosity as it is not necessary to heat them to so high a temperature.

TABLE 1

RELATION BETWEEN DEGREES BAUMÉ, SPECIFIC GRAVITY AND POUNDS PER BARREL (42 GALLON)

Deg. Baumé	Specific Gravity	Lb. per Bbl.	Deg. Baumé	Specific Gravity	Lb. per Bbl.
10	1.0000	350	28	.8861	310
12	.9859	345	30	.8750	306
14	.9722	341	32	.8642	302
16	.9589	336	34	.8537	299
18	.9459	331	36	.8434	295
20	.9333	326	38	.8333	291
22	.9211	322	40	.8235	288
24	.9091	318	42	.8140	285
26	.8974	314	44	.8046	282

Oils are purchased on a volume basis the usual unit being a barrel of 42 gal. As the heating value of oil is reported by weight as B.t.u. per pound, the specific gravity of the oil is an important consideration to the buyer. The specific gravity of oil is given in deg. Baumé. Table 1 gives the relation between deg. Baumé and specific gravity and the corresponding weight of oil per barrel of 42 gal. These data are presented graphically in the chart, Fig. 1.

Representative analyses of fuel oils from three fields are given in the following table. As fuel oil has a relatively high hydrogen content the heating value is given both gross and net. In the net heating value a correction has been made for the latent heat of the water formed by combustion of hydrogen. This correction is equal to 9 times the weight of hydrogen per pound of oil times 1050.

	A California	B Texas	C Mexico
Carbon—per cent	81.0	84.6	83.7
Hydrogen—per cent	11.6	10.9	10.2
Oxygen and Nitrogen—per cent	6.9	2.9	2.0
Sulphur—per cent	.5	1.6	4.1
Heat value B.t.u. per lb.			
Gross	18925	18975	18840
Net	17830	17945	17885
Density degrees Baumé (60 deg. fahr.)	15	21.5	22

The combustion characteristics of the three oils given are shown in the chart on the opposite page. The variation from the values given will be small for all commercial fuel oils.

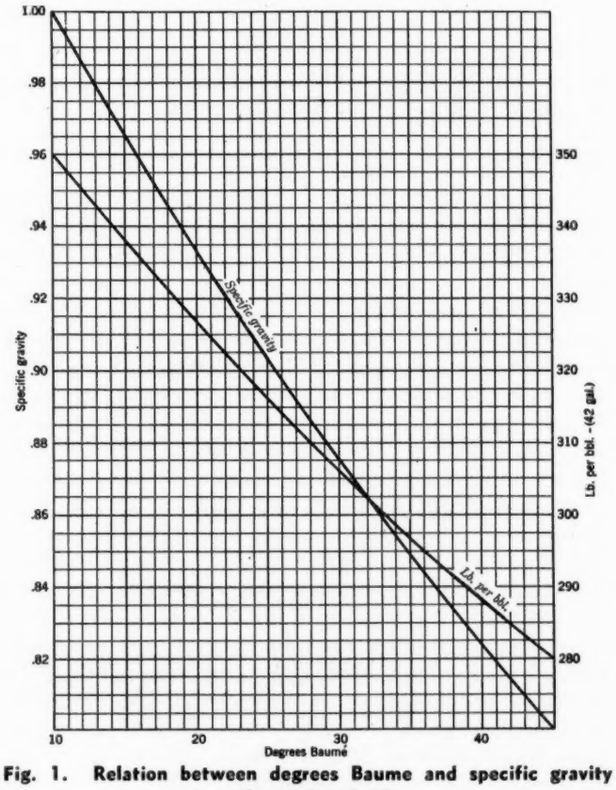

Fig. 1. Relation between degrees Baume and specific gravity and weight of oil.

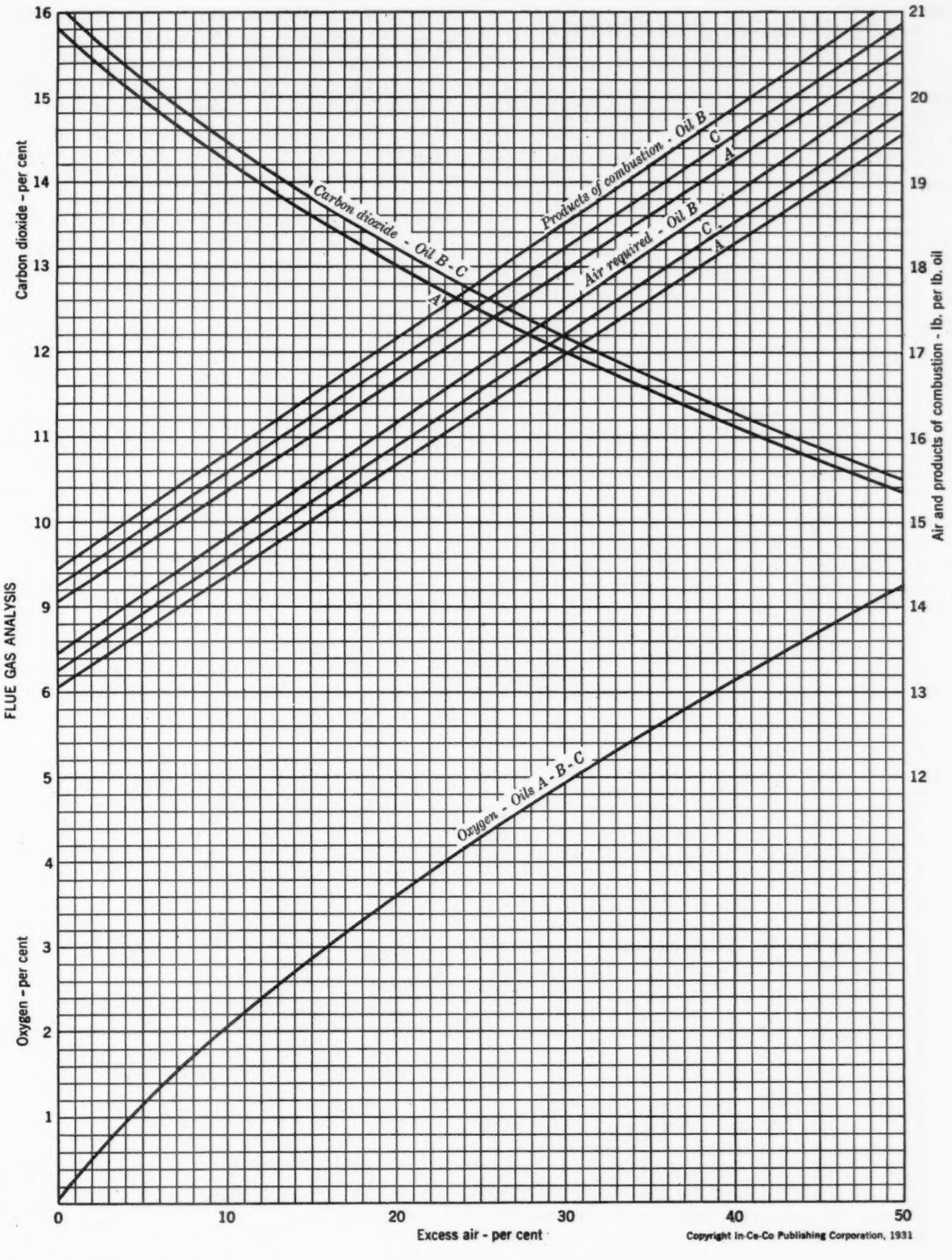

CHART SHOWING COMBUSTION CHARACTERISTICS OF THREE REPRESENTATIVE FUEL OILS

No. 24 of a series of charts for the graphical solution of steam plant problems.

Water Power and Steam

(*Continued from page 46*)

year, the total amount of electricity generated in the United States by fuel-operated plants had increased 158 per cent, as compared with 1919, while the amount of coal consumed to produce it had increased by only 30 per cent. That is real efficiency for you. Our engineers have certainly been on their jobs.

While this production of electricity by fuel-operated plants was increasing by nearly 160 per cent, what was the trend with respect to water power? We find that, in spite of the tremendously increased power requirements of the country, the increase in production by water power was only about 126 per cent—a notable advance, indeed, but not one that would indicate that water power was crowding steam out of the picture. Here is an interesting comparison, while we are looking at these tables: In 1919, 37.5 per cent of the electricity for public use in the United States was produced by water power. Last year the figure was reduced to 34.4 per cent. In other words, the relative importance of water power, as compared to fuel power, in the production of electricity, was less in 1930 than in 1919.

Let us take one more example of the place of water power in the production of electricity at the present time. Last year, the electric power companies of the United States placed in operation additional generating plants of about two and three-quarter millions horsepower capacity. Only about one-quarter of this was in water power; the remaining, nearly three-quarters was in steam.

Without in any sense minimizing the value of water power, whose place in the scheme of electric production today is still a definite and important one, it does not appear likely that it will ever furnish more than its present proportion of the nation's power supply. The matter of its location is all-important, under present conditions. The thought of 65,000,000 horsepower flowing through our streams without any effort being made to utilize it may be a disturbing one to many of us, but unless this potential source of energy can not only be harnessed, but profitably brought to market, it is of no more real importance to us today than the unproductive energy of the tides that rise and fall on our coasts. If the mere presence of potential water power were important as an economic factor, then the Belgian Congo would be the most important water-power center of the world, for the water power resources of that territory are estimated at nearly three times those of the entire United States.

Thus, the place of water power is an important one, although the day has passed when it could be considered a cheap substitute for fuel. It costs nothing only while it is still undeveloped, which is also true of coal, oil, and gas—also gifts of Nature, to that extent. From the point of view of conservation of natural resources, its use is desirable, for as long as rain and snow descend from the skies, water powers will be replenished, and there is, therefore, no destruction of material in their use. On the other hand, the engineering advances that have led to greater productive efficiency in the use of fuels also tend to conserve most effectively our vast coal and oil deposits, in spite of the increasing demand for power. And, as for coal, I believe the most pessimistic of our geologists will admit that mankind has a supply sufficient for at least 10,000 years, and I do not think it is necessary to indulge in any very wild fancy to predict that, long before those hundred centuries have elapsed, our descendants will be obtaining power from new and inexhaustible sources, that will make our present achievements in using water power and steam appear, in comparison, about as efficient as rubbing a couple of sticks together to make a fire.

In these days of earnest discussion of this question it is well to note that the relative positions of methods of power generation are always subject to drastic change. For instance, for years these restless, tireless scientists of ours have been predicting the replacement of the steam plant by the internal combustion engine (like the motor in your car). The large gas engine and the Diesel engine using crude oil are theoretically more efficient than the steam plant; but, up to now, the high cost of construction has generally more than offset the increased efficiency. The gas turbine (at present somewhat of a scientific curiosity) is also receiving increasing attention, and may in time become a most efficient and favored device for power generation.

This question of power sources is worth some thought on the part of every one of us, for electricity today is a good deal more than a convenient means of lighting our houses and saving labor in certain homely tasks. Hardly a product we use has not been fashioned through the intervention of electric power at one stage or another. They have even developed a great turn-table device by which fifty cows are bathed, "atomizered," almost manicured, and then milked—all in 12½ minutes —entirely by electricity. Virtually every sort of industrial and agricultural establishment that supplies our daily needs, from beauty shops to textile mills, all use this power, whether it is generated from water wheels or steam turbines.

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Balancing Supply and Consumption of Energy

(*Continued from page 44*)

through it. The quality of the resulting coke is improved in consequence of the absence of water. In the dry coke-cooling plants the inert gases, heated by the coke gave up their heat to a boiler thus raising steam, and are then again circulated through the coke. The amount of heat recovered by this method is in certain cases so great that the total steam required in the works is raised exclusively in the dry coke-cooling plants.

NEWS

Pertinent Items of Men and Affairs

Annual Meeting American Boiler Manufacturers' Association

At the 43rd Annual Convention of the American Boiler Manufacturers' Association, Skytop Lodge, Skytop, Pennsylvania, on May 25, 26 and 27, H. H. Clemens, of the Erie City Iron Works, was re-elected president; S. G. Bradford, of the Edge Moor Iron Company, was elected vice-president; and A. C. Baker was re-elected secretary and treasurer.

The Executive Committee for the ensuing year is as follows: Homer Addams, Fitzgibbons Boiler Company; George W. Bach, Union Iron Works; Sidney Bradford, Edge Moor Iron Company; F. W. Chipman, International Engineering Works; R. E. Dillon, Titusville Iron Works; E. G. Wein, E. Keeler Company; C. E. Tudor, Tudor Boiler Manufacturing Company; A. C. Weigel, Combustion Engineering Corporation; Ex-Officio—H. E. Aldrich, The Wickes Boiler Company.

The Smoke Prevention Committee of the association reported the results of its contact with the National Smoke Prevention Association and it was announced that the American Boiler Manufacturers' Association would be represented at the next meeting of the National Smoke Prevention Association. William G. Christy, Smoke Abatement Engineer, Jersey City, New Jersey, addressed the meeting. Mr. Christy outlined the constructive smoke abatement program which has been prepared for the coming year and the opportunities for cooperation between the two organizations.

K. Toensfeldt, of Combustion Engineering Corporation, New York, and Chairman of the Feed Water Studies Committee, presented an interesting paper on "Feed Water Conditioning" and outlined the program of the association in connection with this important work.

Dr. Comfort A. Adams, of the Harvard School of Engineering, addressed the convention on "Fusion Welding," a subject of pertinent interest to boiler manufacturers at the present time.

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The Armstrong Cork Company, manufacturer of insulating materials and cork products, consolidated all of its Boston branch sales offices and warehouses at 286 Congress Street, Boston, effective June 15.

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The Ellison Draft Gage Company, Chicago, announces the appointment of the Craun-Liebing Company, 30 Euclid Arcade, Cleveland, Ohio, as exclusive representative in the Cleveland territory including northeastern Ohio.

74 Per Cent of Electricity Generated by Fuels

Utility companies using fuels for generating electricity accounted for 74 per cent of the total generating capacity of 29,532,000 kilowatt hours operated by the power and light industry at the beginning of 1930 and the remainder of 26 per cent used water power, according to a survey by the National Electric Light Association. The investment in plant and equipment necessary for this installed capacity was placed at $11,000,000,000.

An analysis of the financial statements of the companies studied in the survey shows that, on the whole, the investments of fixed capital are relatively greater for hydro-electric companies than for fuel-electric companies. For example, a $10,000,000 hydro-electric unit would have about $9,180,000, or 91.8 per cent of the capital, invested in fixed capital, whereas the fuel-electric company of like size would have fixed assets of $8,750,000 or 87.5 per cent.

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Northern Equipment Company, Erie, Pa., announces the appointment of Joseph W. Eshelman as representative for Copes Feed-Water Regulators, Pump Governors, Differential Valves and allied equipment in Eastern Tennessee. This is an extension of the territory formerly served by Mr. Eshelman from his offices in the Webb-Crawford Building, Birmingham, Ala.

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The Boiler Engineering Company, builder of boiler baffle walls, has moved into more spacious quarters in the new National Newark and Essex Bank Building, 744 Broad Street, Newark, N. J.

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Pyrometer Service and Supply Corporation, 1988 East 66 Street, Cleveland, announces the election of George F. Newell as vice-president and general manager. Mr. Newell formerly represented Charles Engelhard Co., at St. Louis and Chicago.

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The Committee of Ten of the Coal and Heating Industries has established general administrative headquarters, and the National Coal Association has established its Western office at 1715 Bell Bldg., 307 North Michigan Ave., Chicago. Oliver J. Grimes is in charge of the new office and will represent both organizations.

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The Dampney Company of America, Boston, Mass., manufacturer of protective coatings for metals, announces that Murray G. Day, formerly Superintendent of Power of the New Bedford Gas and Edison Light Company, New Bedford, Mass., has joined its organization and will be located at the Chicago office, 53 West Jackson Blvd., Chicago.

NEW EQUIPMENT

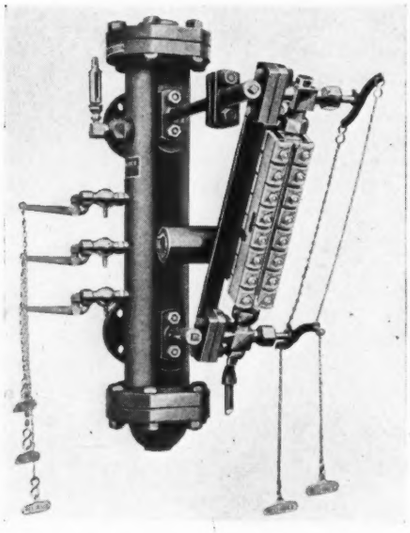
of interest to steam plant Engineers

High Pressure Water Gauge

The Reliance Gauge Column Company, 5902 Carnegie Avenue, Cleveland, has developed the Micasight Water Gauge which ends all the danger, trouble and expense of broken gauge glasses—by the simple expedient of eliminating the glass.

Many of the difficulties experienced with high pressure gauge glasses are due to unavoidable irregularities in the glass and to imperfect installation which set up stresses leading promptly to breakage.

The Micasight Gauge is unbreakable. In continuous service over long periods at pressures as high as 1400 lb., it has demonstrated its ability to stand up under the most severe conditions. The Reliance Micasight, equipped with its illuminator, shows the water line clearly, even from



a great distance, and it maintains this high visibility permanently as neither heat nor corroding agents in the boiler water have any clouding effect on the mica.

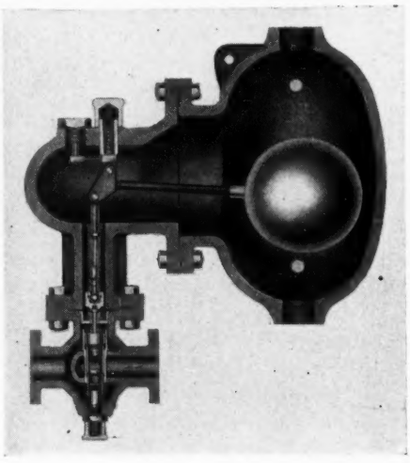
The accompanying illustration emphasizes the simplicity and ruggedness of design. This gauge is available for pressures up to 2000 lb. per sq. in.

Liquid Level Controller

The Mercon Regulator Company, One LaSalle Street, Chicago, has introduced the improved Mercon Liquid Level Controller which may be installed as a drainage controller or as a filling controller.

Mercon valves are equipped with adjustable ports. By rotating the inner cage, any desired flow from zero to full valve capacity may be obtained. This gives the equivalent of a smaller valve for light loads with its more accurate regulation. The valve need not be taken out of service to make this adjustment. A graduated valve travel is provided so that the rate of valve opening is very slow at the beginning, increasing rapidly toward the full open position; thus sensitive control is provided at low rates of flow.

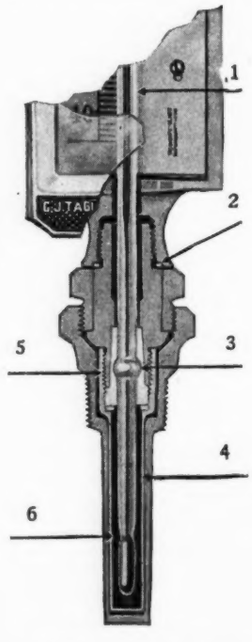
The accompanying illustration shows the filling type controller. By simply in-



verting the fulcrum link and interchanging the connecting mechanism, this valve may be readily converted to a drainage type control.

New Snap-Case Front Industrial Thermometer

The C. J. Tagliabue Manufacturing Company, Brooklyn, N. Y., has recently put into production a new industrial ther-



mometer which has many improvements including a new snap case front.

The glass fronts usually furnished on industrial thermometers get dirty and under certain conditions "fog up." The new TAG snap case front has been designed to facilitate cleaning and at the same time, to make breakage of the removable glass front almost impossible.

Other improved constructional features of this new TAG Industrial Thermometer are shown in the illustration:

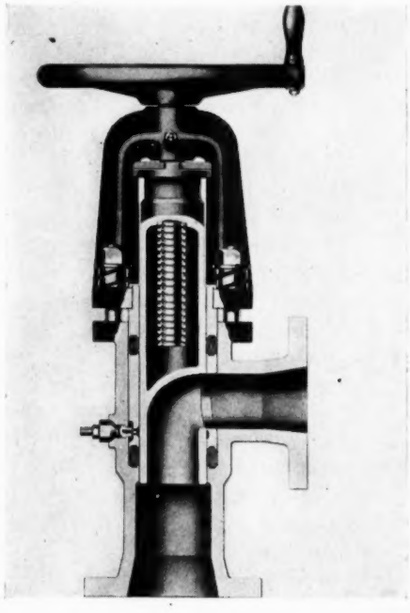
1. TAG-Hespe glass easy to read.
2. Connecting piece, locked to case by a special split spring washer.
3. Asbestos packing, uniformly compressed around enlargement on glass stem prevents movement of the tube with reference to scale.
4. The Monel bulb chamber is thin enough to allow quick conductivity, yet rugged and non-corrosive; cannot amalgamate with the mercury filling.
5. Left hand thread on bulb chamber prevents loosening if case is turned in removing thermometer.
6. Mercury filling in bulb chamber completely surrounds bulb of thermometer thus insuring transmission of heat with great rapidity.

Little effort is required to remove, clean and replace the new front which, when in position on the instrument, is held firmly closed by an ingenious snap device.

Seatless Valves

The Yarnall-Waring Company, Chestnut Hill, Philadelphia, has introduced a new line of valves, for general service use, known as Yarway Type P Seatless Valves.

Utilizing a sliding piston that cuts through highly viscous liquids and solids suspended in solution, this valve closes



tight without the usual danger of foreign matter jamming the valve seat.

The harder the hand-wheel is turned after the valve is closed, the tighter the valve becomes, due to the transmission of this pressure through the upper and lower glands to the packing rings.

When the valve is opened, a clear, unobstructed passage is provided without projections to accumulate deposits.

Yarway Type P Seatless Valves are made in sizes from ¼ in. to 10 in. inclusive. They are fully lubricated by Alemite fittings and are available in various materials. Motor-operated types are available in the larger sizes.

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Elements of Thermodynamics

By Ernest M. Fernald, M.M.E.

THE author of this book states in the preface that its purpose is to impart:

1. An adequate and flexible technique for quantitative dealing with various situations, together with data sufficient for the simpler ones.

2. Clear ideas as to the limitation of engineering practice of universal laws, and as to the conditions that must be met before current practice can approach the ultimate.

The properties, processes, and cycles, of steam and perfect gases are treated with ordinary fullness. Twenty-three pages are devoted to the flow of these substances. Other topics, including refrigeration, evaporation, and compressed air, are treated somewhat less fully. As might be expected in view of the second of the general aims mentioned much is said concerning available energy.

The amount of space devoted to available energy, and the manner of reaching conclusions concerning it, reflect a desire to render this topic more concrete and better understood than it seems usually to be. Generalizations concerning available energy and the Second Law are placed late in the book. This 'higher' thermodynamics is developed from the student's own dealings in the 'lower' thermodynamics of steam and gases, processes and cycles, boilers, engines, and so forth. In short, the student is led up to the Second Law rather than down from it.

The book embodies the more valid results of a thinking-through of the subject by the author after a number of years away from its theoretical aspects. Some advantage may therefore accrue from a partially fresh viewing.

This book is 6¼ by 9¼ overall and contains 330 pages. The price is $3.50.

Internal Combustion Engines

By J. A. Polson

THIS book is intended for students and engineers who have had a thorough course in fundamental thermodynamics, and have some conception of the construction of internal combustion engines. Hence the author has omitted fundamental thermodynamic derivations but has included in the Appendix the more commonly used equations of perfect gases.

In order to avoid confusion to the student, the Otto cycle is first described and developed. Then follows the Diesel cycle.

The theoretical development is treated by the familiar "Air Standard Constant Specific Heat" method and by the "Variable Specific Heat" method. Following the theoretical discussion, performance and test data are presented and analyzed.

Due to the rapid development in the design and manufacture of internal combustion engines, it has been impossible to include many worthy types and makes. Further, the author has confined himself exclusively to American practice.

Typical examples and a few problems are given at various points in the text.

The last chapter is devoted to the subject of testing internal combustion engines and includes information on testing codes and procedure.

This book is 6¼ by 9¼ overall and contains 475 pages. The price is $5.00.

Designing Heating and Ventilating Systems

By Charles A. Fuller

THIS is the third edition of Fuller's handbook, revised and enlarged. It gives a detailed explanation of the methods employed by the most proficient engineers in determining the sizes and proportions of heating and ventilating equipment for all classes of buildings. It treats on the practical application of the engineering rules and formulas in every-day use which are presented in a manner that can be readily understood and applied by those who have not had the advantage of higher technical training.

Beginning with the fundamentals of heat, work and their relations, the author treats of those factors of which an understanding is necessary in order to provide a satisfactory heating and ventilating plant for any kind of building. Heat loss from buildings, classes of heating systems, details of each and the requirements for heating surface, piping systems and boiler plant are discussed with a minimum use of formulas, those used being of simple character.

The arrangement of the book well planned; unessentials have been eliminated and the result is a condensed but complete manual, well adapted for use as a text book in schools and also suitable as a reference book for consulting engineers, architects, and plumbing and heating contractors.

This edition contains 272 pages and has flexible fabrikoid covers, 6 by 9 overall. The price is $3.00.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Air Heater

A new folder describes the Thermix Air Heater, Type C. This heater is of the plate type, consisting of a series of rectangular plates arranged in parallel planes and spaced approximately 1 in. apart. Thus, the gas and air are divided into thin sections passing in counter-current flow through alternate passages between the plates. This design effects efficient heat transfer with practically no maintenance, since there are no moving parts. Gas temperatures up to 1800 deg. fahr. may be used by employing special materials in the heater construction. 4 pages, 8½ x 11—Prat-Daniel Corporation, 183 Madison Avenue, New York.

Feed Pump Regulator

The Mercon Feed Pump Regulator for adjustable excess pressures is presented in new bulletin No. 4-A. The installation is extremely simple, consisting of a regulator, two needle valves and ¼ in. pipe connections. By merely setting the needle valve, any excess pressure from 0 to maximum may be maintained. The regulator is applicable to either centrifugal or reciprocating pumps. 4 pages, 8½ x 11—The Mercon Regulator Company, One LaSalle Street, Chicago.

High Temperature Exhauster

The Thermo Exhauster is insulated and heat-resisting. It is designed to handle gases at high temperatures. Standard designs provide for temperatures up to 900 deg. fahr. and special designs are available for gas temperatures as high as 1800 deg. fahr.

A double housing is provided, one inside the other and separated by an ample thickness of fireproof, heat-resisting insulation. The shaft and bearings are effectively air-cooled and an ingenious cooling device prevents the transmission of heat from the shaft to the bearing. Details of construction are shown in a new bulletin and capacity tables are included. 8 pages, 8½ x 11—Industrial Gas Engineering Company, 201 East Ohio Street, Chicago.

Potentiometer Pyrometers

The new Brown Potentiometer Pyrometer is featured in a new catalog No. 1101. The introduction outlines the potentiometer principle as applied to pyrometers and shows how this principle is incorporated in the new Brown Potentiometer Pyrometer. A concise description of more than fifty features of this new instrument is presented. The instrument has a broad application to industrial needs involving the measurement and control of temperatures, especially in the higher ranges. 48 pages and cover, 8½ x 11—The Brown Instrument Company, Wayne and Roberts Avenues, Philadelphia.

Pulverizing Mill

Raymond Automatic Pulverizers are presented in new catalog No. 22. These pulverizers are applicable to the preparation of a wide range of industrial products. The final chapter of the booklet is devoted to the Raymond Impact Pulverizer which has found wide application for the pulverizing of coal in pulverized fuel burning. The booklet is well illustrated and considerable data are presented on grinding and mill installation for various types of service. 28 pages and cover, 8½ x 11—Raymond Brothers Impact Pulverizer Company, 1315 North Branch Street, Chicago.

Recording Thermometer

New bulletin No. 169 describes Foxboro Recording Thermometers. A complete description of the elements which compose a modern recording thermometer is presented in this booklet. Both vapor tension type and gas-filled thermometers are described. Valuable technical data and engineering information on bulbs, sockets, helical tubes and instrument boards are included. 40 pages and cover, 8½ x 11—The Foxboro Company, Foxboro, Massachusetts.

Smoke and Soot Washer

The American Smoke and Soot Washer is illustrated in a new folder. This device is designed for installation at the top of the chimney and utilizes the principle of reversal of the direction of the gases combined with the use of water sprays in order to remove fly ash, soot and noxious fumes from the stack gases. A number of installations, both in land practice and aboard ship, are illustrated. 6 pages, 8½ x 11—American Smoke and Soot Washer Company, 55 West 42nd Street, New York.

Spray Nozzle

New bulletin No. 6-A describes Schutte and Koerting Spray Nozzles. Water, oil and other liquids are required in spray form in many industrial processes and, to a considerable extent, in power plant work. This catalog presents much data on the selection of spray nozzles for various types of service. Many color illustrations are included and numerous application arrangements are illustrated and described. 32 pages, 8½ x 11—Schutte and Koerting Company, 12th and Thompson Streets, Philadelphia.

Steam Generator

New catalog SG-1 presents the Combustion Steam Generator, a complete unit embodying all of the elements required for steam generation in a simple, compact arrangement, assuring the highest practical efficiency with minimum operating and maintenance costs. The Combustion Steam Generator is available in eight standard sizes providing a wide range of capacities for any desired steam pressure and temperature. Pulverized fuel is introduced at the four corners of a completely water-cooled furnace and is burned with intense turbulent mixing action, the gases leaving the superheater at the top of the furnace, thence through a bank of convection tubes and finally through a plate type preheater and to the chimney. A novel arrangement provides for regulating the temperature of the superheated steam under all conditions of operation. The catalog is well illustrated and dimensions of various sizes are included. 20 pages and cover, 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

Vibration Elimination

"How to Deaden Machine Vibrations and Noise" is the title of a new bulletin which shows how machinery can be isolated by means of natural cork so that noise and vibrations will be eliminated. It explains the advantages of natural cork mats for machinery isolation; gives a table of sizes and shapes of Mundet natural cork mats; and also shows curves of compression tests on mats 1½ in. thick and 3 in. thick. 4 pages, 8½ x 11—L. Mundet & Son, 461 Eighth Avenue, New York.

Water Tube Boiler

Edge Moor Water Tube Boilers, of the Bent Tube type, are presented in new catalog No. 69. Various designs are illustrated and typical setting arrangements are shown in blueprint treatment. A section of the booklet is devoted to manufacturing facilities and shop practices. The illustrations are well chosen and the catalog is particularly attractive. 30 pages and cover, 8½ x 11—Edge Moor Iron Company, Edge Moor, Delaware.

X-Ray Service

A new bulletin gives some interesting information on Metallurgical Radiography, a new science which makes use of the X-Ray to discover inherent defects in metals and metal parts. This science has been highly developed. Steel may be X-Ray-inspected in thicknesses up to 3½ in., aluminum 8 to 9 in. and other metals in equivalent thicknesses. This method of inspection is rapidly gaining recognition because it gives results that are more reliable than are obtained by other methods. A number of interesting examples of X-Ray-inspection are illustrated and analyzed. 4 pages, 8½ x 11—Claud S. Gordon Company, 708 West Madison Street, Chicago.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION

200 Madison Ave., New York